QUANTITATIVE CLINICAL CHEMISTRY

INTERPRETATIONS

VOLUME I

BY

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PREFACE

In the preface to the first edition the origin and purpose of QUANTITATIVE CLINICAL CHEMISTRY were described. It seems well to quote these paragraphs since the authors have attempted to adhere to the same principles in the preparation of this second edition.

"The present volume as well as its companion on methods was begun by one of the authors (P.) some six years ago because of the publishers' suggestion that a handbook which dealt with the subject of quantitative clinical chemistry in a comprehensive manner was needed. At that time only a modest volume describing various analytical procedures and discussing their application to clinical problems was contemplated. Hardly had the work begun, however, before it became apparent that a fragmentary or arbitrary discussion of clinical interpretations would often indicate only a fraction of the causes which can produce a given abnormality, and would fail to provide a logical basis for deducing the actual cause in a given case. It appeared that intelligent interpretation could be best aided by first presenting the physiological conditions, for example, the normal blood content of a given substance, and by then discussing disease effects on such content as the results of quantitative abnormalities in normal processes. The appreciation that such an aim could be better realized by collaboration between chemist and clinician led to the dual authorship.

"It was intended to discuss those substances which are of importance in clinical medicine and for the determination of which suitable quantitative methods are available. Each chapter was to contain a brief account of the physiological rôle of the substance followed by a more extensive discussion of its significance in diagnosis and therapy and a description of analytical methods for its determination. The general plan has been followed; but the physiological sections have filled more space than the clinical applications. This resulted from two reasons: first, because the disease processes are only special examples of extreme functional disturbances and second because so little is known of the changes in disease of some of the substances considered. Finally adequate presentation of physiological and pathological conditions required so much space that the material became uncomfortably bulky for a single volume. It therefore seemed best to consign the methods, which had also outgrown all exceptations, to a second volume, thus providing separately a handbook for the laboratory and a reference book for the study.

"Only in a few outstanding instances has more than passing attention been given to history, although an attempt has been made throughout to cite original work, giving credit for priority where it seemed to be due. The bibliographies are, in most cases, generous, but contain few references that are not mentioned in the text. The compilation of the important literature of a subject which has grown so rapidly seemed to the authors in itself a useful thing. All the articles

have been examined personally by one or other of the authors, with a few unattainable exceptions which are specifically mentioned; and the references even to these have been verified."

When the task of writing the book was first undertaken clinical chemistry was adolescent. Physiological chemistry had concerned itself chiefly with overall effects of metabolism and with certain particular compounds for which practical quantitative analytical methods were available. Of these only a relatively small number had been adapted and applied to clinical purposes. How few these were the chapter headings in the first edition of Interpretations testify, because it seemed to the authors most practical to organize the volume according to the available technical procedures. In some instances the sources of these compounds were unknown; the processes by which the majority were formed were subjects of inference. The study of intermediary metabolism was in its infancy; hormones and vitamins were little more than mysterious vital principles. The Hill-Meyerhof theory of the chemistry of muscular activity stood as a challenging and baffling exploration. The Lipoid chapter, as well as any other, marks the primitive state of the systematic knowledge of the time. Information about the chemistry and physiology of these essential components of food and tissues consisted of the imperfect recognition of a few organic compounds, a scant knowledge of their digestion and absorption and of their concentrations in blood and tissues under limited conditions. The effects of pathological conditions on blood lipids could be uncertainly deduced from isolated observations made by analytical techniques of variable, but always questionable, accuracy. Although it was generally recognized that ketone bodies originated from fatty acids, the manner of their derivation was so much a subject of controversy that it seemed better to place them not in the Lipoid chapter but in a section with other organic acids with which they had nothing in common but their acidic properties. In this same section a place was given to lactic acid, although its relation to carbohydrate metabolism was more clearly recognized. Only in the chapters on Carbohydrate, Hemoglobin and Oxygen, and Carbonic Acid and Acid-Base Balance was it found necessary to devote considerable attention to chemical forces or intermediary processes.

Hardly had the book appeared before the whole complexion of physiological and clinical chemistry changed. When, only a year after its appearance, a second printing was made, the authors felt compelled, besides correcting certain minor errors to which their attention had been called, to recognize the demise of the Hill-Meyerhof theory. This was almost a futile gesture so fast did the revolution advance. With the discovery of the nature of enzymes and their actions, the isolation of hormones and the exploration of intermediary metabolic processes and the forces that control them an entirely new orientation was required. That the volume on Interpretations should still have a place on bookshelves and

readers to move it from time to time is both a surprise and a gratification to its authors.

The first edition had occupied and distracted its authors for eight full years before it was submitted to the public. In 1937 a second edition seemed the only alternative to obsolescence. The latter the authors had been flattered to believe would be unfortunate; there seemed to be a continuing demand for such a volume as Interpretations. Therefore, with misgivings built of experience, it was decided to reedit the volume by the same methods employed in preparing the first. A draft of each chapter, written by one of the partners, was to be submitted to the other for criticism and correction, with the idea that each chapter would travel back and forth as its predecessor had done until it was satisfactory to both authors. Meanwhile, however, both partners had accumulated new responsibilities and preoccupations, while progress in the subject of which they wrote became ever more accelerated. It proved necessary not to reedit but to recompose the text *in toto;* hardly a page of the old volume could be left. The previous format was no longer appropriate. The chapters tended to become marooned and, by the time they were rediscovered, were already obsolete. The offices of the authors threatened to become nothing but graveyards of dead chapters. An almost simultaneous attack on the Methods volume met the same frustration.

Obviously some more promising procedure had to be found. The decision was finally reached that responsibility for the two volumes be divided: Interpretations to be edited by Peters, Methods by Van Slyke. This implies no dissolution of the association, but merely a division of labor. The new arrangement of material was made by joint agreement as more in keeping with the development of the subject matter. Neither volume can be considered the product solely of its responsible author because the concept of the book is a joint achievement built of years of close association. Moreover, ideas and chapters had already been exchanged before the division of responsibility. Although all the chapters in this first volume of Interpretations were initiated and most of them were completed by Peters, marks of Van Slyke will be found in almost all.

With the decision to divide responsibility, it seemed advisable to safeguard the chemical naivete of the clinical partner by providing him additional scientific guidance. The rôle of mentor his colleague, C. N. H. Long, consented to assume. To him thanks are due, not only for criticism and advice, sometimes actual rescue work, but also for considerable contributions, especially in the Carbohydrate chapter. Without his aid the sections on the intermediary metabolism of carbohydrate would be sadly lacking in elegance and authority, the diagrams would not exist, the sections on the glands of internal secretion

would be advanced with less precision and assurance. But these are only the two most prominent features of a debt to one whose patience, interest, encouragement and frankness have made the burden of editing this volume under pressure always less intolerable, sometimes a delight.

Because the subject matter has expanded so rapidly and because it continues to expand at a phenomenal rate, it has been necessary to publish Interpretations in two volumes instead of one. A single volume would be hopelessly bulky. In addition the material covered is so enormous that the last chapter could never have been completed before the first required revision. The first volume is concerned with overall energy exchanges and the chemistry and metabolism of the three major foodstuffs, carbohydrates, lipids and proteins. The chapter on Oxygen and Hemoglobin was to have been included but has been deferred to the second volume because it could not be prepared in time. Besides this chapter the second volume will deal with plasma proteins, water and inorganic elements, including iodine. The first volume is divided into four parts, corresponding to its four major subjects. The subdivision of these parts into chapters has been quite arbitrary, dictated largely by convenience. The bibliographies are indecently long. In this respect the authors have followed the principles established in the first edition of citing all significant original sources. Only when it was impossible to secure the original articles (such exceptions are indicated in the text) has any work been cited that has not been personally examined by one or both of the authors. The assembly of the literature in the first edition elicited so much favorable comment that the authors decided to retain the principle in spite of the intervening accumulation of literature. It is hoped that some to whom the text is unsatisfying may find compensation in the bibliographies through which they may seek more gratifying expositions.

To some the scope of the work will be disappointing. Certain fields of growing importance have been entirely neglected or only touched upon. The effects of vitamins and enzyme systems have been mentioned, but assays for these important elements, their metabolism and their concentrations have not been considered. To have included them would have necessitated an additional volume. Moreover, analytical methods for some are subjects of controversy and the significance of analyses is uncertain. Applications of these procedures to clinical problems have barely begun. The authors have had little or no experience with them.

Besides Dr. C. N. H. Long, whose contributions have already been mentioned, the authors are indebted to numerous others for criticism and advice: to Dr. Abraham White who read the lipid sections and large parts of the section on protein metabolism and offered invaluable suggestions; to Dr. Joseph S. Fruton who surveyed the chemical sections of several chapters; to Dr. Alfred E. Wilhelmi who reviewed the chapters on Creatine and Creatinine and Purines and

Pyrimidines. Without the aid of Dr. Evelyn B. Man the clinical sections of the chapter on Lipids would have had far less value. Numerous references in the bibliography attest the debt owed by the authors to those who have worked with them in their departments. There is not room to name all these associates. Especially thanks are due Miss Mary L. Simuline not only for the meticulous care with which she prepared the copy and checked and rechecked the bibliographies, but also for the patience and good humor which she displayed towards an exacting and capricious author. If errors of format or typography appear, they must be attributed only to her inability completely to surmount this obstacle. In these efforts Miss Simuline was ably assisted by Miss Madeline A. Gallo. For aid in the preparation of the index also, the author is indebted to Miss Simuline.

It is sincerely hoped that this first volume of the second edition of Interpretations will not be a disappointment to those who have awaited its appearance and who have so kindly encouraged the authors to repeat their efforts.

New Haven, Conn. JOHN P. PETERS.

————, 1946.

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PART I

ENERGY METABOLISM

Chapter I

ENERGY METABOLISM

The term metabolism, in its broadest sense, includes all the chemical reactions involved in growth, development and maintenance of the nutritive state of an individual or animal. The problems of chemistry in physiology and clinical medicine can be roughly divided into two classes: (1) those that deal with the nature and extent of chemical reactions that occur in the body; and (2) those which deal with changes in the environment in which these reactions occur and the infinence of these environmental changes on the reactions. Metabolism is concerned chiefly with the former of these, but the distinction between the two is often hard to maintain. The processes of metabolism itself can be divided into two categories: (1) energy-producing reactions, which provide the energy for vital activities; these terminate in oxidative combustions and can, therefore, ultimately be measured in terms of the oxygen consumed; (2) operative reactions which contribute to these activities the specific qualities and direction which make them significant. This chapter aims to review the general aspects of the oxidative or energy-producing reactions of the organism as a whole and the effect of environment upon them. Operative reactions will be considered only so far as is required to establish the setting for the energy-producing reactions. It is hoped in this manner to make more comprehensible subsequent chapters which discuss in detail the individual elements, chemical compounds and groups of compounds which play the most important parts in the determination of reactions and environmental changes concerning which quantitative methods and data are available.

The nature and extent of chemical oxidations determine and are in turn determined by the activities or expenditure of energy in the organism. This energy appears in two forms, external mechanical work and heat. Because of the inefficiency of the muscles as engines, the greater part of the energy appears as heat even during muscular activity; during rest it all appears as heat. Because it is the result of chemical reactions it should also be possible to estimate energy production from the reagents involved and the end products formed. That such estimation is possible was established by Lavoisier, who showed that the production of a given amount of CO_2 by either an animal or a candle was accompanied by evolution of nearly the same amount of heat, thus demonstrating the principle, subsequently further elaborated by Helmholtz, that matter and energy are indestructible. A century later the work terminated by Lavoisier's death on the guillotine was resumed. Through the investigations by Rubner, Pettenkoffer, Atwater and Rosa, Benedict, Lusk, DuBois and others it has been demonstrated that the oxygen used, the carbon dioxide formed and the energy evolved in the oxidation of foodstuffs to CO_2, H_2O and urea are the same whether this oxidation takes place in the body of man

Fats vary greatly in molecular structure and, consequently, in caloric value. The accepted factor for fat is an average of figures obtained by Stohmann (342) for olive oil, fat of animal tissue, and butter fat. Among proteins still greater variations exist. Rubner found the following heat values for 1 gram portions of different proteins: casein, 4.4 Calories; the organic substance of meat, 4.23 Calories; vegetable proteins, 3.96 Calories. He chose as a mean value 4.1, estimating that the ratio of animal to vegetable protein in the average mixed diet would be about 3:2. It is evident that a certain error is involved in the conventional procedure of using these factors indiscriminately for the calculation of the energy value of all diets. This, however, seldom exceeds the errors from other sources that are inherent in all metabolism studies.

THE HEAT VALUE OF OXYGEN AND OF CARBON DIOXIDE IN THE COMBUSTION OF FOODSTUFFS

Carbohydrate. A gram molecule of starch $(C_6H_{10}O_5)_n$ weighs 162n grams and is burned completely by the addition of 6n molecules of oxygen, $6n \times 32 =$ 192n grams of O_2. Therefore 1 gram of starch requires $\frac{192}{162} = 1.185$ grams of oxygen for its combustion. One gram of oxygen, at 0°C. and 760 mm. of Hg occupies 0.6997 liter. Therefore, 1 gram of starch is burned by the addition of $1.185 \times 0.6997 = 0.829$ liter of oxygen. From the process of combustion 4.18 Calories of heat result.[3] Therefore, the consumption of 1 liter of O_2 in the combustion of starch produces $4.18/0.829 = 5.05$ Calories.

By the same method it is possible to calculate the heat value of the carbon dioxide produced in the same reaction. In the case of carbohydrates the number of molecules of carbon dioxide produced is the same as the number of molecules of oxygen consumed, for

$$(C_6H_{10}O_5)_n + 6n(O_2) = 6n(CO_2) + 5n(H_2O)$$

As equal fractions or multiples of the molecular weights of any two gases occupy the same volume at standard conditions, the heat value of a liter of CO_2 is the same as that of a liter of O_2 in the combustion of carbohydrate. It has already been pointed out that the caloric value of a gram of glucose, 3.76, is less than that of a gram of starch, 4.10. The heat value of a liter of oxygen consumed or of CO_2 produced in the combustion of glucose and starch, however, is identical. O_2 consumed for 1 gram glucose $= \frac{192}{180} \times 0.6997 = 0.746$. $\frac{3.762}{0.746} =$ 5.05 = heat value of 1 liter of O_2.

Fat. By similar methods, the heat values of oxygen and carbon dioxide may be calculated for any individual fat from its constitutional formula.

[3] For these calculations Loewy's (213) caloric values are used. See table 1 and explanation in text below.

or in a bomb calorimeter. The nitrogen of protein is not, to be sure, oxidized in the body to HNO_3, as it is in a bomb, but yields less completely oxidized nitrogen-containing compounds, chiefly urea and ammonia. The energy evolved in the change, however, corresponds with that calculated by difference from combustion of the foods and of the nitrogenous compounds which are excreted.

The important sources of energy in animals are proteins, fat, carbohydrate and compounds which can be converted into these substances or their intermediary metabolic products in the body. The end products of the complete oxidation of carbohydrate and fat are carbon dioxide and water; proteins contain also nitrogen and less important amounts of sulfur and phosphorus which are excreted chiefly in the forms of urea and ammonia, sulfuric acid and phosphoric acid respectively. Of these, carbon dioxide is excreted almost entirely by the respiratory system, the oxidation products of nitrogen, sulfur and phosphorus chiefly in the urine, and water in varying amounts through lungs, skin and urine. The oxygen required for the oxidation gains access to the body entirely through the lungs.

THE CALORIC VALUES OF THE DIFFERENT FOODSTUFFS (110, 219, 326)

If the calories produced, the oxygen consumed, and the carbon dioxide produced in the oxidation of a given article of food are known, it is theoretically possible to calculate the heat production from either the O_2 consumption or the CO_2 production. In point of fact this is the general principle underlying all the clinically applicable procedures for the determination of the energy expended in the metabolic processes.

Rubner (312), whose estimates of the caloric values of foodstuffs are generally employed, found that the combustion of 1 gram of carbohydrate yielded about 4.1 Calories; 1 gram of fat, 9.3 Calories; and 1 gram of protein, 4.1 Calories.[1] These values are accurately applicable only to the types of carbohydrate, fat and protein that predominate in the average mixed diet. Individual members of any one of these food classes may have quite different caloric values. The carbohydrate factor, 4.1, for example, holds accurately for starch; 1 gram of glucose produces only about 3.8 Calories. The difference between the two factors depends chiefly on the fact that glucose contains one more H_2O group for each 6 carbon atoms.

$$\text{Glucose} = C_6H_{12}O_6;\ \text{Starch} = (C_6H_{10}O_5)_n$$

[1] The caloric value of protein can not, like those of fat and carbohydrate be determined simply by bomb calorimetry, because certain of the end products of protein metabolism are excreted in feces and urine incompletely oxidized. Rubner (312), therefore, estimated the true caloric value of protein by deducting from the heat of complete combustion the calorific value of the unoxidized residue in feces and urine.

Fats vary greatly in molecular structure and, consequently, in caloric value. The accepted factor for fat is an average of figures obtained by Stohmann (342) for olive oil, fat of animal tissue, and butter fat. Among proteins still greater variations exist. Rubner found the following heat values for 1 gram portions of different proteins: casein, 4.4 Calories; the organic substance of meat, 4.23 Calories; vegetable proteins, 3.96 Calories. He chose as a mean value 4.1, estimating that the ratio of animal to vegetable protein in the average mixed diet would be about 3:2. It is evident that a certain error is involved in the conventional procedure of using these factors indiscriminately for the calculation of the energy value of all diets. This, however, seldom exceeds the errors from other sources that are inherent in all metabolism studies.

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[1] For these calculations Loewy's (213) caloric values are used. See table 1 and explanation in text below.

These figures are not, however, applicable to fats found in foods, which are mixtures of several fats of different composition. For this reason Lehmann, Müller, Munk, Senator and Zuntz (201) adopted another procedure. One gram of lard, a representative edible fat, according to their analyses contained 0.765 gram of C, 0.119 gram of H and 0.116 gram of O_2. From this analysis the heat value of oxygen and of carbon dioxide can be estimated. In order to convert all the H to water, H_2O, $\frac{16}{2} \times 0.119 = 0.952$ gram of O_2 are required. Of this 0.116 is provided by the fat itself and only $0.952 - 0.116 = 0.836$ gram must be obtained from extraneous sources. To convert all the C to CO_2, $\frac{32}{12} \times 0.765 = 2.040$ grams of O_2 are needed and, by means of this, $\frac{44}{32} \times 2.040 = 2.805$ grams of CO_2 are formed. For complete combustion of 1 gram of lard, then, $0.836 + 2.040 = 2.876$ grams of O_2 must be consumed and 2.805 grams of CO_2 are produced. 2.876 grams of $O_2 = 2.876 \times 0.6997 = 2.019$ liters, and 2.805 grams of $CO_2 = 2.805 \times 0.509 = 1.427$ liters.[3] As the combustion of a gram of fat produces 9.46 Calories, the heat value of a liter of O_2 in the combustion of fat $= \frac{9.46}{2.019} = 4.69$ Calories; and that of a liter of $CO_2 = \frac{9.46}{1.427} =$ 6.63 Calories.

Estimations of the same values from the constitutional formulae of the various fats which predominate in ordinary diets give similar results.

Protein. The problem of obtaining factors for the estimation of the heat values of oxygen and carbon dioxide in the combustion of protein is complicated by the fact that the end products of the oxidation of protein are largely excreted in the urine. Loewy (213) found that 100 grams of meat protein contained 52.38 grams C, 7.27 grams H, 22.68 grams O_2, 16.65 grams N and 1.02 grams S. Of this he estimated that there was eliminated in the feces and urine 10.877 grams C, 2.875 grams H, 14.988 grams O_2, 16.65 grams N and 1.02 grams S; leaving 41.50 grams C, 4.40 grams H, 7.69 grams O_2. To oxidize this completely to CO_2 and H_2O 138.2 grams of O_2 must be provided from extraneous sources to form 152.2 grams of CO_2. One gram of protein, therefore, is burned with the consumption of $1.382 \times 0.6997 = 0.9668$ liter of O_2, to produce $1.522 \times 0.5089 = 0.7745$ liter of CO_2. If the caloric value of 1 gram of protein is 4.316, the heat value of a liter of O_2 in the combustion of protein is $\frac{4.316}{0.967} = 4.463$ Calories; that of a liter of CO_2 is $\frac{4.316}{0.7745} = 5.572$ Calories. Of the total nitrogen excreted from 100 grams of protein, Loewy computed that 16.28 grams were eliminated in the urine. Therefore, for every gram of

[3] The factor for converting grams of CO_2 to liters = 0.5089.

urinary nitrogen derived from protein $\frac{96.68}{16.28} = 5.940$ liters of oxygen were consumed, and $\frac{77.45}{16.28} = 4.758$ liters of CO_2 were produced.

RESPIRATORY QUOTIENTS

It is possible from a knowledge of oxygen consumption and carbon dioxide production, to estimate, within certain limits, not only the heat produced by an animal, but also the nature of the food mixture from which this heat was derived. From the discussion in the preceding section it is evident that the ratio of carbon dioxide produced to oxygen consumed, the respiratory quotient, or R.Q., differs according to the character of the foodstuffs burned.

TABLE 1

CALORIC VALUE OF FOODSTUFFS

ONE GRAM OF SUBSTANCE	O_2 ABSORBED	CO_2 FORMED	R.Q.	CALORIES		CALORIES	
				Rubner	Loewy	O_2	CO_2
	cc.	cc.				1 liter	1 liter
Protein	966.3	773.9	0.801	4.10	4.316	4.485	5.579
Urinary nitrogen	5,939.0	4,757.0	0.801	25.63	26.54	4.485	5.579
Fat	2,019.3	1,427.3	0.707	9.3	9.461	4.686	6.629
Starch	828.8	828.8	1.000	4.1	4.182	5.047	5.047

The value of R.Q. is conventionally expressed in terms of *volume of CO_2 produced : volume of oxygen consumed.* A volume ratio is preferable to a weight ratio, because the former is equivalent to a molecular ratio, since a gram molecule of either gas occupies the same volume under identical conditions of temperature and pressure.

From the figures given in the last section the respiratory quotients of the different foodstuffs can be calculated. When carbohydrate is burned, one molecule of carbon dioxide is produced for each molecule of oxygen consumed. Therefore, the R.Q. must be 1.00. In the combustion of lard 2.019 liters of O_2 were consumed with the production of 1.427 liters of CO_2, giving a R.Q. of $\frac{1.427}{2.019} = 0.707$. In the combustion of protein 0.966 liter of oxygen yields 0.774 liter of CO_2 with a R.Q. of $\frac{0.774}{0.966} = 0.801$.

Table 1 gives the caloric values, O_2 consumption, CO_2 production, respiratory quotients, and heat values of oxygen and carbon dioxide for carbohydrate, fat and protein. Duplicate sets of figures are given for caloric values. The second set is that commonly employed for the calculation of metabolism experiments

and was originally derived by Loewy (213). Comparison of these values with those given in the preceding column reveals definite discrepancies. The figures and calculations in the preceding section were taken chiefly from Rubner (312) and are generally used in the computation of the caloric values of diets. The employment of two different sets of factors in the calculation of different aspects of the same metabolism experiment introduces an undesirable and unnecessary inconsistency. As these sections of this chapter are intended less as a treatise on metabolism, than as a guide to the reader who may desire to understand the literature on the subject, no attempt has been made to correct the discrepancies.

COMPLETE CALCULATION OF RESPIRATORY METABOLISM

If, in the processes of metabolism, only one foodstuff is burned, the heat produced can be easily estimated from the heat value of oxygen or of carbon dioxide. If a mixture of foodstuffs is burned, the heat value of oxygen and of carbon dioxide will vary according to the proportions of different foods oxidized. In this case knowledge of either O_2 consumption or CO_2 production alone is not sufficient to permit exact calculation of energy expenditure. For example, if a liter of oxygen were consumed in the combustion of starch, 5.05 Calories of heat would be produced; but the same liter of oxygen would represent only 4.69 Calories if fat were burned. With mixtures of fat and carbohydrate oxygen would have a heat value somewhere between 5.05 and 4.69 Calories per liter.

If only fat and carbohydrate were burned, knowledge of the respiratory quotients would permit the computation of the relative amounts of each in the metabolic mixture. For example, if the metabolic mixture was composed of two-thirds fat and one-third carbohydrate, the respiratory quotient would be $\frac{2}{3} \times 0.71 + \frac{1}{3} \times 1.00 = 0.80$ and the heat value of a liter of oxygen would be $\frac{2}{3} \times 4.686 + \frac{1}{3} \times 5.047 = 4.807$. Table 2 gives the values of respiratory quotients from mixtures of carbohydrates and fats in varying proportions, with the corresponding heat values of oxygen and of carbon dioxide, after Lusk's (222) correction of the table of Zuntz and Schumberg (383). These respiratory quotients are known as *non-protein* respiratory quotients.

If the metabolic mixture is composed of all three foods, carbohydrate, fat and protein, knowledge of O_2 consumed and CO_2 formed will not permit a theoretically exact calculation of heat production. In this case the nitrogen excreted in the urine must also be measured. From it one calculates the amount of protein burned, and hence the O_2 consumed and CO_2 formed in combustion of protein. Subtraction of these quantities of CO_2 and O_2 from the totals leaves the amounts involved in carbohydrate and fat combustion, or the non-protein gas metabolism.

The complete calculation of a metabolism experiment will serve best to illustrate the methods employed in the estimation of heat production and the nature of the metabolic mixture.

TABLE 2

Analysis of the Oxidation of Mixtures of Carbohydrate and Fat (from Lusk) (222)

R.Q.	Percentage of total oxygen consumed by		Percentage of total heat produced by		Calories per liter of	
	Carbohydrate (1)	Fat (2)	Carbohydrate (3)	Fat (4)	O_2 (5)	CO_2 (6)
0.707	0	100.0	0	100.0	4.686	6.629
0.71	1.02	99.0	1.10	98.9	4.690	6.605
0.72	4.44	95.6	4.76	95.2	4.702	6.533
0.73	7.85	92.2	8.40	91.6	4.714	6.459
0.74	11.3	88.7	12.0	88.0	4.727	6.388
0.75	14.7	85.3	15.6	84.4	4.739	6.320
0.76	18.1	81.9	19.2	80.8	4.751	6.252
0.77	21.5	78.5	22.8	77.2	4.764	6.186
0.78	24.9	75.1	26.3	73.7	4.776	6.122
0.79	28.3	71.7	29.9	70.1	4.788	6.062
0.80	31.7	68.3	33.4	66.6	4.801	6.002
0.81	35.2	64.8	36.9	63.1	4.813	5.942
0.82	38.6	61.4	40.3	59.7	4.825	5.883
0.83	42.0	58.0	43.8	56.2	4.838	5.829
0.84	45.4	54.6	47.2	52.8	4.850	5.775
0.85	48.8	51.2	50.7	49.3	4.862	5.722
0.86	52.2	47.8	54.1	45.9	4.875	5.668
0.87	55.6	44.4	57.5	42.5	4.887	5.616
0.88	59.0	41.0	60.8	39.2	4.899	5.566
0.89	62.5	37.5	64.2	35.8	4.911	5.518
0.90	65.9	54.1	67.5	32.5	4.924	5.471
0.91	69.3	30.7	70.8	29.2	4.936	5.423
0.92	72.7	27.3	74.1	23.9	4.948	5.378
0.93	76.1	23.9	77.4	22.6	4.961	5.333
0.94	79.5	20.5	80.7	19.3	4.973	5.288
0.95	82.9	17.1	84.0	16.0	4.985	5.243
0.96	86.3	13.7	87.2	12.8	4.998	5.202
0.97	89.8	10.2	90.4	9.58	5.010	5.163
0.98	93.2	6.83	93.6	6.37	5.022	5.124
0.99	96.6	3.41	96.8	3.18	5.035	5.085
1.00	100.0	0	100.0	0	5.047	5.047

Formula for Column: (R.Q. = R)

(1) per cent $= 100\dfrac{R - 0.707}{0.293}$

(2) per cent $= 100\dfrac{1.00 - R}{0.293}$

(3) per cent $= \dfrac{504.7\,(R - 0.707)}{5.047\,(R - 0.707) + 4.686\,(100 - R)}$

(4) per cent $= \dfrac{468.8\,(1.00 - R)}{5.047\,(R - 0.707) + 4.686\,(1.00 - R)}$

(5) Calories $= 4.686 + \dfrac{R - 0.707}{0.293} \times 0.361$

In one hour a man consumed 13.75 liters of O_2 and produced 11.55 liters of CO_2 and eliminated 0.33 gram of nitrogen in his urine.

The O_2 equivalent of the nitrogen is $0.33 \times 5.94 = 1.96$ liters of O_2.

The CO_2 equivalent of the nitrogen is $0.33 \times 4.76 = 1.57$ liters of CO_2.

The non-protein oxygen absorption is, then, $13.75 - 1.96 = 11.79$ liters.

The non-protein CO_2 production is $11.55 - 1.57 = 9.98$ liters.

The non-protein respiratory quotient $= \dfrac{9.98}{11.79} = 0.85$.

The protein calories, calculated from $O_2 = 1.96 \times 4.485 = 8.8$ Calories.

The non-protein calories, calculated from $O_2 = 11.79 \times 4.86 = 57.3$ Calories (see table 2).

Therefore, the total heat production per hour = 66.1 Calories. Of this 8.8 Calories or 13 per cent were derived from protein; 28.1 Calories or 43 per cent were derived from carbohydrate; and 29.2 Calories or 44 per cent were derived from fat.

Generally accepted methods for the determination of total metabolism may be divided into two chief types: one, *direct calorimetry*, in which actual heat production is measured; the second, *indirect calorimetry*, in which heat production is calculated, as described above, from the oxygen absorbed and the carbon dioxide eliminated by the subject under examination.

Direct calorimetry. To measure heat production directly the experimental subject is enclosed in an air-tight chamber, insulated from changes of environmental temperature and humidity. In this chamber changes in the temperature of the subject (that is, in the heat retained) and in the heat eliminated from the body are measured. Heat is eliminated partly by vaporization of water from the skin and the expired air, partly by simple radiation from the surface of the body, both of which must be separately measured. Vaporization is estimated by collecting and measuring the water eliminated by lungs and skin; radiation, by measuring the increase of the temperature of the calorimeter.

Direct calorimetric studies, besides affording a necessary proof of the accuracy of indirect methods, give information concerning the heat regulating mechanism which can not be obtained from indirect methods. The direct method is, however, impracticable for general clinical or physiological studies because of the cost of installation and maintenance of apparatus, the time and assistance required in its use, and the restrictions it imposes on patients.

Indirect or respiratory calorimetry. Atwater, Benedict, Lusk and DuBois and their associates (109, 219), by comparisons of direct and indirect calorimetry under a variety of conditions, have established the fact that the energy production of both animals and man can be accurately estimated from measurements of oxygen consumption and CO_2 production. Apparatus employed for these measurements is of two general types, the so-called "closed" and "open circuit" machines.

In the open types air, inspired by the subject from the outside atmosphere, is expired into an appropriate receptacle for a given period, at the end of which the collected expired air is measured and analyzed for oxygen and carbon dioxide. In the closed types of apparatus the subject rebreathes continuously air enriched with oxygen, which is made to circulate through the apparatus and from which the carbon dioxide produced and the oxygen absorbed are measured gravimetrically or volumetrically.

Under certain standard conditions described below in the section on *Basal Metabolism*, heat production can be estimated from oxygen consumption alone, with the assumption that the respiratory quotient is relatively constant. It must be emphasized that techniques which permit the measurement of oxygen consumption alone are applicable only to the determination of basal metabolism.

(For a detailed description of acceptable methods see the chapter on *Respiratory Metabolism* in the *Volume on Methods*.)

Because carbon dioxide can be measured more easily and accurately than oxygen, instruments which are intended to measure basal metabolism by determination of carbon dioxide production alone have, from time to time, been recommended (186, 187) and put on the market. There are, however, cogent reasons for believing that CO_2 output is inherently less reliable than O_2 intake for the estimation of basal metabolism. From table 2 it can be seen that, with a given change of R.Q. the caloric value of a liter of CO_2 changes about four times as much as does the caloric value of a liter of O_2. Hence a deviation of the subject's R.Q. from the assumed R.Q. will cause more error in the metabolic rate if this is calculated from the CO_2 output. Secondly, because of the nature of the chemical combinations in which carbon dioxide exists in the body, its elimination can be influenced by changes in the acid-base equilibrium of the organism and by respiratory disturbances unrelated to metabolism. This is far less true of oxygen. For these reasons methods dependent upon the measurement of CO_2 alone have not been accepted by the most meticulous workers. In fact, even when both oxygen and carbon dioxide are measured, the former is used for the calculation of heat production.

Recently Poulton (292) has advanced a new argument for the use of CO_2. In analyzing data from experiments of Benedict and Carpenter and DuBois in which direct and indirect calorimetry were compared, he discovered that the two methods agreed closely only when the R.Q. was about 0.785. At lower R.Q.'s heat production estimated from oxygen consumption exceeded the heat production directly measured; at higher R.Q.'s there was a discrepancy of opposite sign. From the same data Poulton found that whereas the oxygen consumption bore this variable relation to the heat determined by direct calorimetry, CO_2 production bore a fairly constant relation. He concludes that the R.Q's of normal persons do not denote the proportions of fat and

carbohydrate oxidized. He postulates a combustion mixture containing fat and carbohydrate in constant proportions of 1.3 grams fat to 1.0 gram carbohydrate. Fluctuations of the R.Q. he attributes to conversion of variable amounts of carbohydrate to fat (elevating the R.Q.), and of fat to carbohydrate (depressing the R.Q.). CO_2 production he supposes remains constant and proportional to heat production, while oxygen varies according to the quantities utilized for these conversions. Poulton's proposal, built on few selected data secured in the postabsorptive state,[4] would destroy at one stroke a structure based on much more extensive evidence derived not only from studies of respiratory metabolism, but by a variety of other methods. It postulates conversion of fat to carbohydrate, for which there is no adequate proof. Poulton confines himself to consideration of normal postabsorptive metabolism. If a constant metabolic mixture were consumed under these circumstances and no others, normal and abnormal metabolism would be so sharply differentiated that measurement of the respiratory exchange would be of no value in the study of disease or disordered physiologic states.

Estimation of metabolism from evaporation of water

If the mean temperature of the body is to remain constant, as it does in homothermic animals, heat production and heat dissipation must be equal. Therefore, so long as the body temperature remains constant, it is possible to determine heat production by the measurement of heat loss. The latter is effected by vaporization of water from skin and expiratory air and by radiation from the surface of the body. Under conditions of basal metabolism it has been found by Soderstrom and DuBois (333) and confirmed by others (158, 205) that in the average subject approximately 24 per cent of the total heat lost from the body escapes by evaporation of water from the lungs and dry skin. Evaporation of 1 gram of water at 37° absorbs 0.581 great calory of heat. If, then, a subject in the basal state is losing 0.24 per cent of the calories produced by vaporization of water, it is possible to estimate the metabolic rate from the insensible perspiration—that is, the water lost through skin and respiratory passages without obvious activity of the sweat glands. The total energy production is $\frac{1}{0.24}$ or 4.16 Calories for each Calory lost from the body by

[4] Rosenbaum (310) in an analysis of the same data found that the systematic error to which Poulton attached significance appears in the studies of only 2 of the 3 subjects of Benedict and Carpenter's experiments. In the observations on these 2 subjects energy-production, as measured by respiratory exchange, is quite constant, while heat elimination, as measured by direct calorimetry, is consistently higher in initial periods than it is in subsequent periods. This suggests a systematic error in the direct procedure, presumably in the measurement of changes of mean body temperature. The R.Q. decreases progressively in the course of each experiment as fasting is prolonged. For this reason the discrepancies between the two methods appear to be correlated with the R.Q. Examination of other data from humans and animals revealed no such correlation (264, 310).

evaporation, and each gram of water vaporized absorbs 0.581 Calory of heat. Therefore

(1) $$\text{Total Calories} = 4.16 \times 0.581 \times IW = 2.42 \times IW$$

IW represents grams of water in insensible perspiration.

Estimation of metabolism from insensible perspiration

"Insensible perspiration" is defined as the loss of body weight not referable to excreted urine and feces, under conditions in which sensible sweating does not occur (33). It comprises the weight lost by way of the skin and lungs, which consists of evaporated water, and the difference between CO_2 lost and O_2 absorbed. The relation of the total weight lost by insensible perspiration, IL, to the water lost in the insensible perspiration, IW, is represented, then, by the equation,

(2) $$IL = IW + (CO_2 - O_2)$$

in which all values are expressed in grams.

Whereas the evaporated water, IW, can be measured only by highly complicated procedures such as those employed in the methods for direct calorimetry, the total insensible perspiration can be measured by merely comparing the intake of food and fluids with the output of urine and feces and the change of body weight.

Calculation of basal metabolism from insensible perspiration. If it is assumed that the R.Q. is 0.82 and if the slight effects of protein are neglected, with the aid of the factors in table 2 it can be calculated that 1/4.825 or 0.207 liter of oxygen are consumed and 1/5.883 or 0.170 liter of CO_2 are produced for each Calory of heat liberated. The gravimetric equivalents are 0.296 gram of O_2 and 0.334 gram of CO_2. From equation 1 the weight of insensible water, IW, per Calory of heat produced is 1/2.24 or 0.413 gram. Substituting these values in equation (2),

$$IL = 0.413 + 0.334 - 0.296 = 0.451$$

Whence the heat produced per gram of insensible perspiration lost is $\frac{1}{0.451}$ or 2.21 Calories and

(3) $$\text{Total Calories} = 2.21 \times IL$$

Calculation for other than basal conditions. For these conditions, with any R.Q., Johnson and Newburgh (179) proposed a method of calculation based upon the following assumptions: first that the quantity of water vaporized from skin and lungs bears a constant relation to heat production; second, that all carbohydrate which is ingested is burned; third, that urinary nitrogen provides

an accurate measure of protein metabolism. The calculation procedures involved have been simplified into the following equations (200, 283, 286)

$$\text{(4)} \qquad IL = (W_1 - W_2) + (w_i - w_e)$$

in which W_1, W_2, w_i and w_e represent, respectively, initial and final body weights and weights of intake and excreta.

$$\text{(2)} \qquad IW = IL - (CO_2 - O_2)$$
$$\text{(5)} \qquad WB = (H_2O_i - H_2O_e) + (H_2O_{ox} - IW)$$

in which WB is the water balance, H_2O_i and H_2O_e the amounts of water in the food and the excreta respectively and H_2O_{ox} the quantity of water produced in the oxidation of the food mixture consumed. By combination of these three equations

$$\text{(6)} \qquad WB = (W_2 - W_1) + (w_e - w_i) + (H_2O_i - H_2O_e) + (H_2O_{ox} + CO_2 - O_2)$$

$W_2 - W_1$ represents the weight balance, while $w - H_2O$, the weight of intake or excreta minus water, represents solids. Furthermore, from the values of

TABLE 3

WATER AND GAS EXCHANGE IN THE COMBUSTION OF FOODSTUFFS

ONE GRAM OF SUBSTANCE	O_2 ABSORBED	CO_2 FORMED	H_2O FORMED
	grams	grams	grams
Protein	1.382	1.522	0.396
Fat	2.876	2.805	1.071
Starch	1.185	1.629	0.556

oxygen absorbed and carbon dioxide and water formed in the combustion of foodstuffs (see table 3), it will be seen that $H_2O_{ox} + CO_2 - O_2$ is, for fat 1.0, for carbohydrate 1.0 and for protein 0.54. This term, therefore, becomes $C + 0.54\,P + F$, in which C, P and F represent, respectively, the grams of carbohydrate, protein and fat burned. The previous equation, therefore, becomes

$$\text{(7)} \qquad \begin{array}{ccccccc} WB & = & (W_2 - W_1) & + & (S_e - S_i) & + & (C + 0.54\,P + F) \\ \textit{Water balance} & = & \textit{Weight balance} & + & \textit{Solids lost} & + & \textit{Food burned.} \end{array}$$

Of these terms change of body weight may be determined on an accurate balance; the solids of intake and excreta may be measured by weighing food, drink, urine and feces before and after the water has been driven off. The food burned, however, can be estimated only by indirect methods: P from the nitrogen excreted, C from the carbohydrate ingested, and F by subtracting the calories derived from the protein and carbohydrate from the total calories expended. This last is calculated from the insensible water loss by equation (1),

(1) $$\text{Cals.} = 2.42\ \text{IW}$$

From table 3

$$CO_2 - O_2 = 0.42\ C + 0.14\ P - 0.07\ F$$

and

$$\text{Cals.} = 4.1\ C + 4.1\ P + 9.3\ F$$

If all these values are substituted for their respective terms in equation (2)

$$\text{IL} = \frac{4.1C + 4.1P + 9.3F}{2.42} + 0.42C + 0.14P - 0.07F$$

$$= 2.12C + 1.69P + 3.78F$$

or (8) $$F = \frac{\text{IL} - 2.12C - 1.69P}{3.78}$$

The complete determination of water balance or total metabolism, therefore involves the following steps:

1. Weighing the subject at the beginning and close of the experimental period.
2. Weighing all fluids and food taken by the subject and all the excreta.
3. These measurements give the data required for calculation of the insensible loss of weight by equation (4).
4. Estimating the carbohydrate content of food from dietary tables or by analysis.
5. Analyzing the excreta for nitrogen.
6. With the assumption that all carbohydrate eaten is burned and that protein oxidized is equal to nitrogen excreted $\times$ 6.25, fat consumed can be calculated by means of equation (8).
7. For the estimation of the water balance by equation (7) the weights of dried substance of intake and excreta must also be determined.

As a means of estimating basal or total metabolism, measurement of insensible perspiration is far less reliable than respiratory or direct calorimetry. It has the advantage, however, of wide applicability because of the relatively simple apparatus and procedures required. It has been employed for the determination of basal metabolism by several observers (33, 78, 181), and has been applied by Newburgh and his collaborators (179, 268) to the estimation of the total energy consumption of subjects engaged in the light activities of ordinary life.

Although the average normal subject under basal conditions loses 24 per cent of the total heat produced by evaporation of water, the deviations from this average are large even in health and may become larger in disease (142, 200, 333). If the body temperature of the subject changes during the examination an error is introduced, since any change of temperature indicates an inequality between heat produced and heat lost. Sensible perspiration entirely invali-

dates the procedure. Sweating is a physiological process aimed to increase heat loss by evaporation. When active sweating begins, the proportion of heat lost by evaporation may increase quite rapidly (136, 377). In addition sweat may fall from the body or be absorbed by clothes and bedding, thus escaping vaporization on the body. Water thus lost as liquid from the skin has no value in the elimination of heat.

When the method is applied to the measurement of total metabolism it is subject to the same sources of error. In addition Heller and Schwartz (158) found, from a statistical analysis of all published experiments in which both total heat production and water of vaporization were measured directly, that when heat production exceeded 2200 calories the proportion of heat lost by vaporization fell below 24 per cent. This is not more than 50 per cent higher than the normal basal rate. DuBois and Hardy (111) also found that slight exercise, such as shivering or pretended shivering, altered the proportions of heat lost by vaporization, radiation and convection.

In calculations of the total metabolism from insensible perspiration there are certain other sources of error. The estimation of the food value and the measurement of the solids of the ingesta are subject to considerable error (200). The assumption that all carbohydrate that is eaten is immediately burned is not entirely consistent with the facts. In spite of these difficulties the method has proved useful for the measurement both of water balance and energy expenditure during physiological experiments on selected subjects (180) under controlled conditions. It is of little clinical value.

For more extensive discussion of the subject see Lavietes (200) and Peters (283, Chap. VII).

THE INTERCHANGEABILITY AND STORAGE OF DIFFERENT FOODSTUFFS

Conversion of carbohydrate to fat (219) (see also chapter on Carbohydrate Metabolism). Carbohydrates and fat may be used indiscriminately for the production of heat and energy. If, at any time, more carbohydrate becomes available than can be used for immediate combustion, the excess may be stored in the body for future use. The amount of this that can be laid up in the liver and other tissues as glycogen is, however, limited.

Amounts of carbohydrate in excess of the glycogen capacity can only be stored after they have been converted to fat. During such conversion respiratory quotients may rise above unity, in animals as high as 1.3 or 1.4, because a substance rich in oxygen is converted into one which is relatively poor in oxygen. The conversion also involves the expenditure of a certain amount of energy. Evaluations of the energy expenditure and the respiratory quotient of the conversion have been made by a variety of methods that involve the assumption of intermediate reactions, although these are unknown, and the estimation of the heat value of the so-called "extra CO_2" evolved (219). The general

order of magnitude of these values can, however, be estimated more easily by a direct method, based on the chemical composition and the caloric value of fat and carbohydrate. It is assumed that any extra energy required for the conversion is derived from the combustion of carbohydrate and that carbons not directly utilized for formation of fat are oxidized to carbon dioxide. The formation of tristearin from glucose may be selected as an example, because this will require greater energy expenditure and will yield a higher respiratory quotient than will any shorter acid or the conversion of starch.

1 gram molecule of tristearin, $C_{57}H_{110}O_6$ = 890 grams.

9.5 gram mols. of glucose are required to provide the carbons to form tristearin = $C_{57}H_{114}O_{57}$ = 1710 grams.

The caloric value of 890 grams of tristearin = 890 × 9.3 = 8270 Cals.

The caloric value of 1710 grams of glucose = 1710 × 3.8 = 6498 Cals.

This leaves a deficit of 8270 − 6498 = 1772 Cals.

Therefore, to form 1 gram mol. of tristearin, in addition to the 9.5 gram mols. of carbohydrate required to provide the necessary number of carbons, enough glucose must be consumed to furnish an extra 1772 Calories. The caloric value of 1 gram mol. of glucose = 180 × 3.8 = 684 Calories. The number of molecules of glucose required for extra energy production, is then 1772/684 = 2.6.

This means that for each mol. of glucose converted to tristearin 2.6/9.5 = 0.27 additional mol. must be burned, or 1 extra mol. for each 3.7 mols. converted to tristearin. The problem can be stated in another manner. If the caloric values of 1 gram mol. of tristearin and glucose, respectively, are 8270 and 684, then 8270/684 = 12.1 mols. of glucose will be required to produce the Calories produced by 1 mol. of tristearin; but only 9.5 mols. of glucose are required to provide the carbons for 1 mol. of tristearin.

These are minimal figures for the energy expended in the conversion. They evaluate within the accuracy of the factors used, however, the deficit of heat in the transformation, if nothing but carbohydrate is involved, because the extra heat spent in energizing this transformation will not appear in calorimeter measurements, during the transformation. It can not be used for the production of energy immediately; but is stored in the fat to be liberated again only when the fat is burned.

From the structure of tristearin and carbohydrate it is evident that the conversion of 9.5 mols. of glucose to 1 mol. of tristearin will involve the loss of 51 O + 4 H or 2 H_2O + 24.5 O_2, without the production of any CO_2. The combustion of the extra 2.6 mols. of glucose will require the consumption of about 15.5 mols. of O_2 with the production of an equivalent amount of CO_2 and H_2O. The total reaction, therefore, will result in the production of about 9 mols. of O_2 and 15.5 mols. of CO_2.

In actual point of fact, of course, elimination of oxygen in excess of CO_2 is

dates the procedure. Sweating is a physiological process aimed to increase heat loss by evaporation. When active sweating begins, the proportion of heat lost by evaporation may increase quite rapidly (136, 377). In addition sweat may fall from the body or be absorbed by clothes and bedding, thus escaping vaporization on the body. Water thus lost as liquid from the skin has no value in the elimination of heat.

When the method is applied to the measurement of total metabolism it is subject to the same sources of error. In addition Heller and Schwartz (158) found, from a statistical analysis of all published experiments in which both total heat production and water of vaporization were measured directly, that when heat production exceeded 2200 calories the proportion of heat lost by vaporization fell below 24 per cent. This is not more than 50 per cent higher than the normal basal rate. DuBois and Hardy (111) also found that slight exercise, such as shivering or pretended shivering, altered the proportions of heat lost by vaporization, radiation and convection.

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Amounts of carbohydrate in excess of the glycogen capacity can only be stored after they have been converted to fat. During such conversion respiratory quotients may rise above unity, in animals as high as 1.3 or 1.4, because a substance rich in oxygen is converted into one which is relatively poor in oxygen. The conversion also involves the expenditure of a certain amount of energy. Evaluations of the energy expenditure and the respiratory quotient of the conversion have been made by a variety of methods that involve the assumption of intermediate reactions, although these are unknown, and the estimation of the heat value of the so-called "extra CO_2" evolved (219). The general

order of magnitude of these values can, however, be estimated more easily by a direct method, based on the chemical composition and the caloric value of fat and carbohydrate. It is assumed that any extra energy required for the conversion is derived from the combustion of carbohydrate and that carbons not directly utilized for formation of fat are oxidized to carbon dioxide. The formation of tristearin from glucose may be selected as an example, because this will require greater energy expenditure and will yield a higher respiratory quotient than will any shorter acid or the conversion of starch.

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This means that for each mol. of glucose converted to tristearin 2.6/9.5 = 0.27 additional mol. must be burned, or 1 extra mol. for each 3.7 mols. converted to tristearin. The problem can be stated in another manner. If the caloric values of 1 gram mol. of tristearin and glucose, respectively, are 8270 and 684, then 8270/684 = 12.1 mols. of glucose will be required to produce the Calories produced by 1 mol. of tristearin; but only 9.5 mols. of glncose are required to provide the carbons for 1 mol. of tristearin.

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In actual point of fact, of course, elimination of oxygen in excess of CO_2 is

never observed. This is not difficult to understand. The conversion of carbohydrate to fat is not an energy-liberating, but an energy-consuming process. While it is proceeding the energy needs of the animal must be maintained by the synchronous combustion of other fuel which will have a major influence upon the overall respiratory quotient. This can be illustrated by another example.

Let it be assumed that an individual is using 2000 calories per day, of which 250 is derived from protein, the remaining 750 from carbohydrate. In addition enough carbohydrate to make 1000 calories is used to form fat.

1750/3.8 = 460 grams of glucose, spent for energy production, requires the consumption of 343 liters of O_2 and the production of 343 liters of CO_2.

1000/3.8 = 263 grams of glucose will be used for the formation of fat. Of this 55 grams will be burned to provide energy for the conversion, with the consumption of 41 liters of O_2 and the production of 41 liters of CO_2.

The remaining 208 grams of carbohydrate will produce 108 grams of fat, with the liberation of 63.5 liters of O_2.

The resultant overall non-protein respiratory quotient, then, will be

$$\frac{CO_2}{O_2} = \frac{343 + 41}{343 + 41 - 63.5} = \frac{384}{320.5} = 1.20 = \text{R.Q.}$$

If starch were substituted for glucose in these calculations the respiratory quotient would be about 0.06 lower. If tripalmitin were substituted for tristearin it would be still lower. In any case the estimations serve to indicate the order of magnitude of the energy consumption and the respiratory quotients that attend the formation of fat from carbohydrate. They also demonstrate clearly that even the most rapid production of fat from carbohydrate can not raise the overall respiratory quotient far above 1.00. Certainly it can never change the sign of the overall respiratory quotient. Nevertheless, the transformation of itself does liberate oxygen; it also causes the storage of energy. Consequently, when the conversion of carbohydrate to fat is proceeding at a sufficiently rapid rate to yield a non-protein respiratory quotient greater than 1.00, neither direct nor respiratory calorimetry is a true measure of energy production and the two can not be expected to agree. However, so long as the non-protein R.Q. lies between 0.71 and 1.00, it indicates accurately the net destruction of carbohydrate and fat, even if some carbohydrate has been transformed to fat during the period of operation.

From the standpoint of energy-production and the nature of the fuel consumed by the body it is a matter of complete indifference whether carbohydrate is burned directly or after intermediate conversion to fat. Furthermore, because the respiratory quotients of the two processes are identical, there is no means of distinguishing them. From the standpoint of physiology, however, great significance attaches to the fact that there are alternative routes for the

metabolism and combustion of carbohydrate. The assumption that only gross excesses of carbohydrate are converted to fat arises from the general doctrine that fat in the storage depots is relatively inert material, mobilized only when it is required to serve as fuel. This static concept of tissue fat is untenable, since Schoenheimer and Rittenberg (321) have shown that there is a constant and rapid exchange of fatty acids in the fat depots. It is highly probable that some carbohydrate is at all times converted to fat and that the metabolism of carbohydrate through this channel becomes accelerated under certain physiologic or pathologic conditions not necessarily connected with the provision of excessive quantities of carbohydrate. In no other manner could the well fed animal, receiving large amounts of carbohydrate at intervals during the day, spread the utilization of this food over the whole 24 hours. The capacity of the glycogen stores in the liver is altogether too limited. The fat depots are, however, highly distensible. By means of heavy water Stetten and Boxer (339a) have recently shown that when a well-fed rat is given glucose, the major part of the sugar which is not burned directly is converted to fat, not to glycogen, before combustion. The fasted rat, on the other hand, converted a far larger proportion of glucose or lactic acid to glycogen (50a).

The site of the conversion of carbohydrate to fat is not definitely known, but recent work suggests that the adipose tissue itself is capable of bringing about the transformation. Tuerkischer and Wertheimer (364) have observed that when starved rats are placed on a diet rich in carbohydrate, glycogen in quantities as great as one gram per cent may accumulate in the adipose tissue along with fat for periods up to 4 days after realimentation. They suggest that not only can the adipose tissue synthesize glycogen, but it can also effect the conversion of this carbohydrate to fat. In a further paper from the same laboratory Mirski (260) reports that the adipose tissue of rats is able to phosphorylyze glycogen to glucose-1-phosphate and to synthesize glycogen from this ester. The respiratory quotient of adipose tissue, taken from rats after carbohydrate feeding and suspended in a glucose-serum medium, averaged 1.25; while even tissue from fasted rats in the same medium yielded an average R.Q. of 1.15. Evidently the tissue was able not only to synthesize and oxidize carbohydrate, but also to convert a portion of the carbohydrate to fat. Tepperman (353), using a different technique, has come to a similar conclusion. He measured, after subcutaneous injection of glucose, the respiratory gas-exchange of rats which had been trained to ingest large quantities of a carbohydrate-rich diet in the short space of one to three hours. The average respiratory quotient was 1.25, which fell to 0.95 after evisceration, but rose again to 1.16 when insulin was injected. Evidently the peripheral tissues were able to convert a portion of the injected glucose to fat, provided an adequate rate of carbohydrate oxidation was maintained.

It has been rather generally assumed that if less carbohydrate is fed than is

never observed. This is not difficult to understand. The conversion of carbohydrate to fat is not an energy-liberating, but an energy-consuming process. While it is proceeding the energy needs of the animal must be maintained by the synchronous combustion of other fuel which will have a major influence upon the overall respiratory quotient. This can be illustrated by another example.

Let it be assumed that an individual is using 2000 calories per day, of which 250 is derived from protein, the remaining 750 from carbohydrate. In addition enough carbohydrate to make 1000 calories is used to form fat.

1750/3.8 = 460 grams of glucose, spent for energy production, requires the consumption of 343 liters of O_2 and the production of 343 liters of CO_2.

1000/3.8 = 263 grams of glucose will be used for the formation of fat. Of this 55 grams will be burned to provide energy for the conversion, with the consumption of 41 liters of O_2 and the production of 41 liters of CO_2.

The remaining 208 grams of carbohydrate will produce 108 grams of fat, with the liberation of 63.5 liters of O_2.

The resultant overall non-protein respiratory quotient, then, will be

$$\frac{CO_2}{O_2} = \frac{343 + 41}{343 + 41 - 63.5} = \frac{384}{320.5} = 1.20 = \text{R.Q.}$$

If starch were substituted for glucose in these calculations the respiratory quotient would be about 0.06 lower. If tripalmitin were substituted for tristearin it would be still lower. In any case the estimations serve to indicate the order of magnitude of the energy consumption and the respiratory quotients that attend the formation of fat from carbohydrate. They also demonstrate clearly that even the most rapid production of fat from carbohydrate can not raise the overall respiratory quotient far above 1.00. Certainly it can never change the sign of the overall respiratory quotient. Nevertheless, the transformation of itself does liberate oxygen; it also causes the storage of energy. Consequently, when the conversion of carbohydrate to fat is proceeding at a sufficiently rapid rate to yield a non-protein respiratory quotient greater than 1.00, neither direct nor respiratory calorimetry is a true measure of energy production and the two can not be expected to agree. However, so long as the non-protein R.Q. lies between 0.71 and 1.00, it indicates accurately the net destruction of carbohydrate and fat, even if some carbohydrate has been transformed to fat during the period of operation.

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tion of the case for the conversion of fat to carbohydrate the reader is referred to a review by Soskin (335).

Conversion of protein to carbohydrate and fat (109, 110, 219, 322). Since animals receiving solely or almost entirely protein can maintain or even replenish their stores of glycogen and fat, it can be inferred that protein can be converted to both fat and carbohydrate.

The starved or meat-fed dog which is rendered totally diabetic by phlorizin or by removal of the pancreas, excretes glucose and nitrogen in proportions that approach a comparatively fixed value. If the urinary glucose is all derived from protein and no carbohydrate can be burned, this ratio of urinary glucose to nitrogen, the G:N ratio, will serve as a measure of the quantity of carbohydrate derived from protein. In early experiments Lusk (219) and his associates found that after phlorizin the G:N ratio of the starving or meat-fed dog reached a maximum of about 3.65. On the assumption that all the sugar was derived from protein and that the highest attainable ratio would represent conditions under which the greatest possible amount of carbohydrate was produced, it was estimated that $\frac{3.65}{6.25}$ (6.25 is the factor to convert nitrogen to protein) or 58 per cent of protein could be converted to glucose. It is now generally believed that this estimate, for a long time widely accepted, is probably too high. It has been repeatedly noted, since the earliest studies of Minkowski, that the G:N ratio of the depancreatized dog seldom exceeds 2.8 to 3.0. There is no *a priori* reason to believe that removal of the pancreas gives a less severe diabetes than phlorizin does. Moreover, many observers have been unable to reproduce with phlorizin such high ratios as Lusk reported. Even the ratio of 2.8 to 3.0 of the depancreatized dog may be an over-estimation since, as Shaffer (322) pointed out, part of the glucose excreted by the diabetic dog, whether phlorizinized or depancreatized, is presumably derived, not from protein, but from the glycerol of fat which is burned at the same time. Shaffer suggested, on the basis of the earlier estimates, that this would reduce the G:N ratio from 3.65 to about 3.00, which would mean that only 48 per cent of protein could be converted to glucose. If the overall ratio is reduced from 3.65 to 3.00, correction for glycerol of fat would bring it still lower, just how much lower it is impossible to say. When all the available evidence is weighed, no precise mathematical definition appears to be warranted. It is necessary at

Before these conclusions can be accepted the observations must be confirmed and subjected to analysis by other methods. Certain metabolic processes are known to proceed step-wise. For example, fatty acids are converted in the liver to ketones, which are burned in the muscles. The respiratory quotient of ketone formation itself is extremely low. Therefore, if the production of ketones for a time greatly exceeded their oxidation, the respiratory quotient might fall below 0.71; it could not fall as low as 0.3 unless metabolism in all tissues except liver ceased.

needed for the energy requirements of metabolism, it is burned in preference to fat. It has also been assumed frequently that if an individual is given sufficient carbohydrate, fat and protein to meet his metabolic demands, he will burn the food given rather than his own tissues. These assumptions are not always valid. Richardson and Mason (301), by means of the respiration calorimeter, determined the quantities of endogenous protein, fat and carbohydrate oxidized by diabetic patients at rest. When this endogenous diet was replaced by an identical food mixture with the addition of considerable quantities of fat, respiratory quotients indicated that the patients often oxidized more protein and carbohydrate and less fat than they received. In other words they burned protein and carbohydrate derived from their own tissues and utilized a portion of the dietary fat for storage. When, because of the absence of carbohydrate from the diet, the glycogen of the liver is reduced and the conduct of metabolism is taken over by protein and fat, oxidation of carbohydrate becomes greatly retarded. Under these conditions, if carbohydrate is administered its oxidation is not immediately accelerated. For a distinct interval the load of metabolism continues to be borne by protein and fat, while carbohydrate is stored as glycogen. A similar sequence of events seems to follow the restoration of the ability to burn carbohydrate in the diabetic animal. Likewise, when carbohydrate is removed from the diet, protein and fat do not take over the whole load until liver glycogen is greatly depleted.

Conversion of fat to carbohydrate (109, 110, 219, 322, 335, 336, 337). (See also chapters on Carbohydrate and Lipids.) Glycerol, fed as such, is quantitatively converted to glucose or can be used for formation of hepatic glycogen (76, 96). Experiments by Deuel (96) indicate that glycerol derived from the hydrolysis of fats is subjected to the same metabolic processes. It is extremely doubtful whether glucose can be formed from the fatty acid fraction of fat. The totally diabetic animal excretes in the urine no more glucose than can be derived from protein and other known precursors of glucose. Since fat contains a far smaller proportion of oxygen than carbohydrate does, the conversion of fat to carbohydrate would require the consumption of a relatively large amount of oxygen and would yield a respiratory quotient far lower than 0.71, that of pure fat. Stadie (336, 337) was unable to detect any evidence of glycogen production from fat in the livers of diabetic animals, nor was the oxygen consumed by these livers sufficient to permit the transformation of fat to carbohydrate. Although respiratory quotients below 0.71 have been reported, their authenticity has been questioned.[1] For the most recent presenta-

[1] Werthessen (372), in continuous records of the respiratory exchange of rats fed only once in 24 hours, observed fluctuations of R.Q. from as low as 0.3 to as high as 1.7 in the course of the day, although the average R.Q. for periods of 24 to 30 hours lay in the generally accepted range. He suggests that over a short period the R.Q. may be a measure, not of the proportions of fat and carbohydrate burned, but of intermediate transformative reactions.

insufficient calories in the form of carbohydrate and fat, the deficiencies of the diet are supplied from his own tissues. Since the preformed stores of carbohydrate in the body are limited, after a short time the metabolic mixture consists chiefly of protein and fat. By the administration of adequate or excessive amounts of carbohydrate, under these circumstances, protein wastage may be minimized, although it can not be abolished. Apparently the organism utilizes protein, when the supply is limited, as economically as possible, for those functions which protein alone can serve, expending it for simple energy-production only when other fuel is not available. In the absence of exogenous carbohydrate it is compelled in addition to supply enough glycogen to maintain the indispensable operative and energy-producing offices of carbohydrate. Fat usually need not be provided because it can be secured from the fat depots. Even if these are depleted, minimum nitrogen metabolism can not be attained by the administration of fat alone because this can not replace carbohydrate. But, if large amounts of fat are available only small quantities of carbohydrate are required to achieve a maximum economy of protein (see chapter on Net Nitrogen Metabolism).

NATURE AND SOURCES OF FECAL MATERIAL

(See chapters on Carbohydrates, Lipids and Net Nitrogen Metabolism)

Examination of the feces of any person reveals the presence of nitrogen and fatty acids, amounting, on an ordinary mixed diet, to about 10 per cent of the ingested protein and less than 10 per cent of the fat. A part of the fecal fat and protein may represent unabsorbed food products; part is derived from intestinal secretions. The nitrogen and the fatty acids in the feces remain relatively constant when dietary protein and fat are varied. They may be increased by the addition to diets of roughage, by the presence of diarrhea or pancreatic insufficiency, or by the administration of indigestible forms of protein or fat.

Stools contain only minimal quantities of reducing substances. A certain proportion of ingested carbohydrate may escape absorption to fall prey to bacteria and other carbohydrate-fermenting organisms in the intestinal tract. The quantity which escapes absorption can not be estimated; but, from metabolism experiments on phlorizinized animals, it would appear to be negligibly small.

Whether the nitrogen and fat in stools be looked upon as unabsorbed or as excretory materials, they must be taken into consideration in any attempt to strike a balance between diet and metabolism.

THE RELATION OF EXCRETION TO PRODUCTION OF METABOLIC END-PRODUCTS

In the last analysis metabolism studies that depend upon the analysis of excreta of any kind are acceptable only if there is reasonable assurance that the

present to be content with the statement that as carbohydrate metabolism is reduced to a minimum, the G:N ratio approaches as a limit a value of about 3.0, indicating that the glucose formed from average protein can not exceed in weight 48 per cent of the weight of the protein.

It can not be too much emphasized that no inferences can be drawn from G:N ratios derived from short periods of observation with changing diet. Glycogen swept out of the liver will give spurious high values, storage of glycogen will have the opposite effect.[6] (For more detailed discussion see chapter on Carbohydrate, p. 141.)

Another portion of the protein molecule, after deamination, forms fatty acids. It is frequently stated that these are used to form fats. This is highly improbable, since it has been repeatedly demonstrated that short-chain fatty acids can not be used for the construction of the long-chain fatty acids found in fats. It is possible that the deaminated fatty-acid residues may be converted to ketone bodies. It seems necessary to suppose that fat which is formed from protein must be derived from the residues that form carbohydrate and that it may involve preliminary conversion to carbohydrate (for further discussion, see chapter on Carbohydrate, p. 139 and chapter on Lipids, p. 409).

Neither fat nor carbohydrate can replace protein entirely in the diet or the metabolic mixture because neither contains the necessary nitrogen, sulfur or amino acids. Animals appear to be unable to synthesize certain essential amino acids from simpler nitrogen-containing compounds. They also seem to have a limited capacity to store protein as such. If an excess of protein is fed daily to a well nourished animal some of the nitrogen may be retained in the first few days; but at the end of that time nitrogen equilibrium is again attained. When the supply of amino acids provided by the food proteins exceeds the needs of the body for replacement of tissue proteins, the excess, after deamination, is burned for immediate energy production or used for formation of fat or carbohydrate. Of course an exception to this general rule is found when there is a demand for growth or for restoration of tissue. Under these circumstances, if conditions are favorable, protein will be retained. A persistent retention of nitrogen for the deposition of protein in the body is, therefore, usually regarded as evidence of growth or of previous protein starvation.

If the diet fed to an individual contains little protein and, at the same time,

[6] Drury (104) has recently claimed that the G:N ratio is actually as high as 5 to 6, which would require that 80 to 96 per cent of protein be converted to glucose. It has been established independently that only certain amino acids can be converted to glucose. The quantities of these amino acids in the proteins fed by Drury would preclude such high quotients. There is no certainty that an equilibrium was secured in the experiments, the animals received at times either glucose or protein. In some instances also insulin was given. Finally, the methods of calculation are open to criticism.

insufficient calories in the form of carbohydrate and fat, the deficiencies of the diet are supplied from his own tissues. Since the preformed stores of carbohydrate in the body are limited, after a short time the metabolic mixture consists chiefly of protein and fat. By the administration of adequate or excessive amounts of carbohydrate, under these circumstances, protein wastage may be minimized, although it can not be abolished. Apparently the organism utilizes protein, when the supply is limited, as economically as possible, for those functions which protein alone can serve, expending it for simple energy-production only when other fuel is not available. In the absence of exogenous carbohydrate it is compelled in addition to supply enough glycogen to maintain the indispensable operative and energy-producing offices of carbohydrate. Fat usually need not be provided because it can be secured from the fat depots. Even if these are depleted, minimum nitrogen metabolism can not be attained by the administration of fat alone because this can not replace carbohydrate. But, if large amounts of fat are available only small quantities of carbohydrate are required to achieve a maximum economy of protein (see chapter on Net Nitrogen Metabolism).

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materials analyzed represent accurately the products of the processes under investigation. A lag in the excretion of these products or the sudden sweeping out of material under the influence of extra-metabolic factors introduces distinct errors.

The influence of changes in ventilation on the respiratory excretion of carbon dioxide (see chapter on Carbonic Acid and Acid-Base Balance). Carbon dioxide exists in the blood and tissues partly in simple solution, partly in combination with base, as bicarbonate, and, to a small extent, in combination with hemoglobin as carbhemoglobin. If the carbon dioxide tension or the bicarbonate concentration of such a mixture is altered, the carbon dioxide eliminated by the respiratory system will change accordingly. Although the CO_2 which is driven off or bound by these influences has no metabolic significance, it will affect the respiratory quotient.

The direction and extent of the distortion of CO_2 produced by changes of bicarbonate or CO_2 tension in the blood or tissues depend on the manner in which these changes are brought about. Recent studies by Hastings and associates (157) indicate that the membranes of tissue cells permit the free passage of CO_2 or carbonic acid, but are impervious to the bicarbonate ion. If, therefore, the CO_2 tension of the blood is reduced, as it may be when a nervous individual, unused to respiratory apparatus, breathes in excess of his physiological needs, large amounts of carbon dioxide may be pumped out of the tissues as well as the blood. Such over-ventilation may, in extreme cases, as DuBois (110) has pointed out, raise the R.Q. from 0.77 to 1.10 and the metabolism calculated from the carbon dioxide excretion will be correspondingly high, although the energy expenditure of the individual is unappreciably altered. Nervous hyperventilation of this kind, which is known as "Auspumpung," is usually transitory and is succeeded by a compensatory period of hypo-ventilation in which the R.Q. may fall below 0.70. This, and the fact that the respiration during such nervous breathing is seldom regular, lead to its detection. Except after a high carbohydrate feeding resting respiratory quotients above 1.00 are presumptive evidence of "Auspumpung." A disturbance of the opposite order could be produced by involuntary hypo-ventilation; but this is of less practical importance because restraint of respiratory activity provokes so much discomfort that it can not be maintained for more than a brief interval.

Because of the selective permeability of the tissue cell membranes primary alterations of bicarbonate or of acids other than carbonic have a variable effect upon CO_2 elimination, apparently depending on the point at which they are initiated. The simple addition of bicarbonate to blood induces minimal changes of respiration; most of the bicarbonate is retained in the blood and interstitial fluids and is excreted in the urine (310). The administration of ammonium chloride also has an inappreciable effect on respiratory CO_2 elimina-

tion and R.Q., even when enough is given to lower serum bicarbonate 2 to 4 volumes per cent in the course of an hour (310). Ammonium chloride acts like hydrochloric acid, Cl displacing bicarbonate and releasing CO_2. This must increase the CO_2 tension. However, the chloride is confined to the extracellular fluids. A large part of the CO_2 liberated, apparently, is transferred to the tissue cells, where it is neutralized by the abundant buffers, instead of being excreted in the expired air. At most only the CO_2 derived from extracellular bicarbonate may be eliminated by the lungs; the cellular bicarbonate will remain untouched.

The response to increases of acid within the cells is quite different. In this case the CO_2 tension within the cells rises owing to the liberation of CO_2 from bicarbonate. The former diffuses out of the cells to increase the CO_2 tension of the blood. This stimulates the respirations to eliminate more CO_2. The sequence of events is best illustrated by the observations of Hill, Long and Lupton (169) on the effects of exercise. During severe exercise a large amount of lactic acid accumulates in the muscle cells and body fluids because the supply of oxygen to the exercised muscles is inadequate. The lactic acid is neutralized in part by the reaction $HLa + BPr = BLa + HPr$, with the protein buffers represented as BPr. In part, however, it is neutralized by the reaction $HLa + BHCO_3 = CO_2 + H_2O + BLa$. This decomposition of bicarbonate with liberation of CO_2 increases the tension, within the cells, of CO_2, which therefore diffuses into the extracellular fluids and blood. The lactic acid also escapes from the cells to decompose the bicarbonate of the extracellular fluids and blood in the same manner. CO_2 tension in both cellular and extracellular fluids increases. Consequently, during lactic acid accumulation the R.Q. rises because to the CO_2 formed from burned fat and carbohydrate is added the CO_2 formed from decomposed bicarbonate. Furthermore, in contrast to the hydrochloric acid derived from ammonium chloride, lactic acid releases CO_2 in cells as well as extracellular fluids. Even after brief violent exercise is stopped the R.Q. continues to rise for some minutes because O_2 intake falls more rapidly than CO_2 output. At this time the R.Q. may touch a peak value as high as 2.0. Later, during recovery, when the lactate disappears and frees its alkali to recombine with CO_2, a compensatory reduction of R.Q. to 0.70 or less can be observed.

Formulae have been proposed by means of which respiratory quotients may be corrected for changes of blood bicarbonate (324); but no one of them is of any practical value because respiratory elimination of CO_2 from bicarbonate of the body is not directly related to changes of the concentration of bicarbonate in blood. More depends on the means by which the bicarbonate is altered. For example, voluntary or involuntary hyperventilation may pump out of the tissues in a short time a large quantity of CO_2 with only an insignificant reduction of the CO_2 content or bicarbonate concentration of the blood; while

R.Q. may not be demonstrably altered by a dose of ammonium chloride that will lower blood bicarbonate by two to four volumes per cent (310). If there is reason to suspect that blood bicarbonate or CO_2 tension may change during the determination of metabolism by means of the respiratory gas exchange, the CO_2 content of the blood or serum should be measured at the beginning and end of the determination. If it has changed, the estimation of metabolism so far as this may be influenced by the valne of R.Q., must be interpreted with reserve.

The effect of non-metabolic disturbance of respiration on oxygen absorption. Because the hemoglobin of arterial blood of normal persons is, at sea level, almost completely saturated with oxygen, "Auspumpung" and the over-ventilation caused by acid have little effect on O_2 absorption. It is on this account that, under standard conditions, when the R.Q. can be assumed to be relatively constant, heat production can be calculated from oxygen consumption alone with little error. Under other conditions when the R.Q. and, consequently, the heat value of oxygen may be expected to vary, the same factors which are sources of error in the estimation of CO_2 production, by affecting the respiratory quotient, introduce a similar, though smaller, error into the computation of metabolism from both carbon dioxide and oxygen.

In exercise the absorption of oxygen, if estimated over short periods, may afford no accurate measure of energy production. If the exercise is sufficiently severe, it results at first in the anaerobic conversion of glycogen to lactic acid and, during the exercise, the oxygen absorbed falls short of the heat generated. This is the same stage of exercise in which non-metabolic CO_2 excretion is at its height. During this period the muscles run up an "oxygen debt." In the subsequent recovery period, which lasts for some time after the exercise has ceased, oxidative processes are called into play. During this period the rate of oxygen-absorption exceeds that of energy-production. In order to determine either the true respiratory quotient or the true heat production during exercise, therefore, it is necessary to measure oxygen-absorption and carbon dioxide-production from the start of exercise until the completion of the recovery period. When the Hill-Meyerhof theory of muscular activity prevailed, it was believed that the oxygen-debt was incurred altogether through the anaerohic formation of lactic acid and was repaid to permit the combustion of part of the lactic acid and the reconversion of the remainder to glycogen. Measurements of the time relations between the repayment of the [illegible] and the removal of lactic acid as well as the quantitative re[illegible] acid removed to the oxygen consumed during the recovery [illegible] to be incompatible with this theory. It is necessary to [illegible] aerohic reactions or incomplete oxidations, the nature o[illegible] known, which are completed during oxidative reco[illegible] speedier than the reconversion of lactate to glycogen.

sumably, take place in the skeletal muscles themselves, whereas lactate is transformed to glycogen in the liver or may be burned by other organs, such as the heart, brain and testes. (See chapter on Carbohydrate.)

THE TIME RELATION BETWEEN NITROGEN EXCRETION AND NITROGEN METABOLISM

(See chapter on Net Nitrogen Metabolism)

Under normal conditions of diet and living in health, it can probably be assumed with little error that the nitrogen excretion of any given twenty-four-hour period represents fairly accurately the nitrogen production and, therefore, the protein metabolism of that period. If, however, the protein in the diet is suddenly increased or diminished, the same assumption can not be made. After such a change in diet a period of two or more days may elapse before nitrogen equilibrium is established. This lag appears to be due chiefly to the sweeping out or retention of mobile protein stores.

Divergence between catabolized nitrogen and excreted nitrogen may also result from sweeping out or retention of non-protein nitrogen. If the ability of the kidneys to excrete nitrogen is impaired, or the volume of urine is low in comparison with the nitrogen catabolism, non-protein nitrogen may accumulate in the blood and tissue fluids with great rapidity. On the other hand, if the ability of the kidney to excrete nitrogen rapidly improves, or if the volume of urine increases out of all proportion to the nitrogen catabolism, non-protein nitrogen may be quickly swept out of the body.

The influence of these sudden changes in N-excretion which are entirely unrelated to metabolic nitrogen production can be detected and estimated if observations are made of changes in blood non-protein nitrogen, body weight and urine volume.

Attempts to correlate nitrogen excretion with protein metabolism over periods shorter than twenty-four hours are open to more serious criticism. After any meal containing protein the non-protein nitrogen in the blood may rise appreciably and remain elevated for four hours or more, particularly if the amount of fluid taken with the meal has been relatively small. There is, in this case, a regular and definite lag in the excretion of the products of protein catabolism. If the ability of the kidney to excrete N is impaired this lag is greatly prolonged. In nephritis with hyposthenuria, nocturnal polyuria is regularly observed. Because the patient is unable to excrete a sufficiently concentrated urine, the nitrogen produced in the active diurnal metabolism must be excreted during the course of the night.

In comparisons of dietary protein with nitrogen metabolism and excretion it is usually assumed that all the nitrogen in the diet is protein nitrogen, and dietary protein is calculated as dietary N $\times$ 6.25 (the factor for converting N to protein). The error introduced by this assumption is small. An uncertain fraction of the nitrogen in food is, however, non-protein nitrogen. Part of this,

of course, passes through the body without contributing to energy production or any other useful function.

The nitrogen of normal urine is usually almost entirely non-protein nitrogen and may, therefore, properly be considered as the product of more or less complete protein oxidation. The chief fraction consists of urea + ammonia and may be considered as completely oxidized. A small fraction is excreted in less completely oxidized form, partly (1 or 2 per cent of the total N) as amino acids. The urea + ammonia fraction may be regarded as the product of protein that has been expended for general purposes, including the production of energy. It is this fraction which fluctuates with the dietary intake of protein. The remaining fraction, which is far more constant and but little influenced by diet, has been utilized for operative purposes. The two fractions are end products of different metabolic processes and must, therefore, represent different amounts of energy expenditure. The employment of a constant factor for the computation of energy-production from urinary nitrogen is, accordingly, inexact, although it is unavoidable until more is known of the intermediary metabolic processes by which the various nitrogenous products are formed.

In some normal urines and many pathologic urines protein itself is excreted in varying and often considerable quantities. Nitrogen excreted as protein presumably has been of no value to the organism either from the standpoint of energy production or tissue nutrition. Although urinary protein nitrogen must be considered a source of protein wastage and included in determining nitrogen balances, only non-protein nitrogen may be used for the estimation of protein catabolism and heat production.

BASAL METABOLISM (27, 43, 110, 187, 244, 350)

The term "basal metabolism" is used to indicate the rate of heat production measured in the morning, twelve to fourteen hours after the last meal, when the subject is lying down and motionless. Under these conditions the energy production of normal individuals is lower than it is at any other time while the subject is awake. It falls to a still lower level during sleep (236). Krogh (196) has proposed the term "standard" and Benedict prefers "postabsorptive" as more accurately descriptive than "basal"; but the last has been generally adopted in this country.

The basal metabolism varies with age, sex and size according to more or less well established rules; but is fairly constant in a given individual or in similar individuals of the same species. In adult males of the same age and size it seldom deviates by more than 10 per cent from the mean standard, a variation no greater than that observed in single individuals on different days.

Size. In persons of the same age and sex, basal metabolism varies with both height and weight and appears to be most closely correlated to surface area.

DuBois and DuBois (106) have derived a formula by which the surface area of an individual may be calculated from height and weight:

$$A = H^{0.725} \times W^{0.425} \times 71.84$$

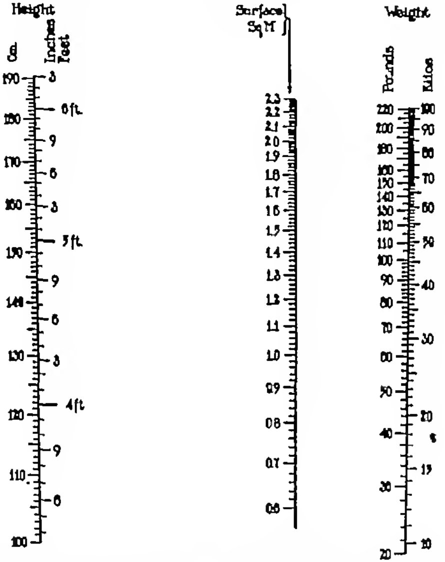


FIG. 1. Nomogram permitting direct estimation of surface area from height and weight by DuBois' formula $A = H^{0.725} \times W^{0.425} \times 71.84$. When A = surface area in square centimeters, H = height in centimeters and W = weight in kilos. (sq. cm. = sq. m. × 10,000.) The surface area is found at the point of intersection of the middle scale with a straight line drawn from the observed height on the left hand scale to the observed weight on the right hand scale.

when A = surface area in square centimeters (square meters × 10,000), H = height in centimeters, and W = weight in kilos. By means of the d'Ocagne monogram of figure 1, surface area, according to the DuBois formula, can be estimated from height and weight without arithmetical calculation.

Various observers (28, 102, 156, 196) have proposed other formulae which are claimed either to measure area more accurately or to give a more exact correlation with the basal metabolism. Of these the only ones which have been extensively used are the age-weight-sex and height-weight-sex tables of Harris and Benedict (156). The relative merits of various standards have been discussed at length by DuBois (110) and Boothby and Sandiford (45). For most subjects standards based on weight alone, or weight and height, are suitable, since there is a general correlation between weight, height and form. The surface area formula appears to be more universally applicable than others because it gives better predictions in subjects of unusual shape.

Age. The basal metabolism in proportion to size, however this may be estimated, varies distinctly at different ages. In early infancy it is low, but rises rapidly during the first months of life, to reach a maximum from which it declines gradually during the major part of the growth-period. The early peak has been variously placed between the second and fourth years. From data of Lewis, Kinsman and Iliff (207), who have investigated the subject with great care, it must occur before the second birthday because, from this point on until the thirteenth birthday, the basal metabolism per square meter of surface area bears an inverse linear relation to age, which is defined by the following equations.

For boys

Calories per square meter per hour = 1.20 years of age + 56.70.

For girls

Calories per square meter per hour = 1.382 years of age + 55.364.

These equations probably provide the best means of prediction now available for the particular ages to which they are applicable, from the second to the thirteenth birthday. The authors estimate that 99.7 of boys should fall within ±18 per cent of this mean standard and 95 per cent within ±12 per cent; the corresponding deviations for girls are ±16 and ±11 per cent.

It is generally held that basal metabolism rises out of proportion to size during pubescence (55, 363), since in this period chronological age seems to be less important than the stage of development, with which it is but roughly correlated. Both the standards of Harris and Benedict and those of Boothby and Sandiford must be applied with caution to any particular case (216, 246, 338). Shock (326a) has recently examined the subject carefully and offered standards based on age and surface area which allow more accurate prediction. Between the twentieth and fortieth year the basal metabolism maintains a fairly constant level, and it is during this period that prediction standards are most useful. In old age the basal metabolism again declines (14, 29); but it is uncertain whether this is an effect of age *per se* or only evidence of the declining vigor and fitness that accompany the advance of age in the average run of persons (29).

TABLE 4A

NORMAL VALUES OF BASAL OR STANDARD METABOLISM

(A modification of the DuBois standard (47))

AGE	CALORIES PER SQUARE METER PER HOUR		AGE	CALORIES PER SQUARE METER PER HOUR	
	Male	Female		Male	Female
years*			years		
5	(53.0)	(51.5)	20	41.0	36.5
6	53.0	50.5	21	40.5	36.5
7	52.0	49.5	22–24	40.0	36.5
8	51.0	48.0	25–29	39.5	36.5
9	50.0	46.5	30–34	39.0	35.5
10	49.0	45.5	35–39	38.5	35.0
11	48.5	44.5	40–44	38.0	35.0
12	47.5	43.0	45–49	37.5	34.5
13	47.0	42.0	50–54	37.0	34.0
14	46.0	41.0	55–59	36.0	34.0
15	45.0	39.5	60–64	35.5	33.5
16	44.0	38.5	65–70+	35.0	33.0
17	43.5	37.5			
18	42.5	37.0			
19	42.0	36.5			

* In using the table the age should be determined to the nearest year. That is, 4 years 6 months to 5 years 5 months inclusive, is taken as 5 years; to do this correctly the actual birthday must be known

TABLE 4B

MEAN VALUES OF BASAL OR STANDARD METABOLISM

(An extension of the DuBois standards to the early years of life (207))

AGE	CALORIES PER SQUARE METER PER HOUR		AGE	CALORIES PER SQUARE METER PER HOUR	
	Male	Female		Male	Female
years*			years		
2	54.3	52.6	8	47.1	44.3
3	53.1	51.2	9	45.9	43.0
4	51.9	49.8	10	44.7	41.6
5	50.7	48.5	11	43.5	40.2
6	49.5	47.1	12	42.3	38.8
7	48.3	45.7	13	41.1	37.4

* This refers to the actual age. For example 2 years refers to the second birthday. Interpolation should be employed to obtain the value at the nearest quarter year. Instead of the table the following equations may be employed:

For boys:

Cals. per sq. m. per h. = 1.20 age in years + 56.70.

For girls:

Cals. per sq. m. per h. = 1.382 age in years + 55.364.

Sex. From the age of 2 onwards, if not before, the basal metabolism of females is distinctly lower than that of males of the same size. From the prediction equations of Lewis, Kinsman and Iliff (207), the difference is only 4 per cent at the age of 2 and increases to 9 per cent at 13. During adult life and old age it amounts to 7 to 10 per cent (110, 156).

Normal standards. Tables 4a, 4b and 4c give the normal standards for prediction of basal metabolism. The authors prefer these standards based on surface area to those which utilize only weight or height (28, 34, 69, 102, 156) because the correlation with surface area is superior, especially in subjects who deviate from the average in structure. For children from 2 to 13 years of age table 4b, from Lewis, Kinsman and Iliff (207), is probably more accurate than 4a; between 11 and 18 years table 4c, from Shock (326a), is to be preferred. It will be noted that there is a considerable difference between the standards

TABLE 4c

Mean Values of Basal or Standard Metabolism

(An application of the DuBois standards to the adolescent period of life (326a))

Age	Calories per square meter per hour		Age	Calories per square meter per hour	
	Male	Female		Male	Female
years			*years*		
11.5	43.6	41.7	15.0	42.8	35.7
12.0	45.0	41.0	15.5	41.4	34.4
12.5	44.4	40.4	16.0	41.1	34.2
13.0	44.1	39.9	16.5	41.0	34.6
13.5	43.2	38.8	17.0	40.9	33.4
14.0	43.5	38.0	17.5	40.6	33.4
14.5	42.9	36.5			

predicted by tables 4b and 4c and those in 4a. This results in a sharp break at the 14 year point if table 4b is used with 4a. The standards of Lewis et al and of Shock are distinctly lower than those of Boothby and Sandiford. Shock has suggested that this difference may be referable to climate. This seems improbable. The standards of Lewis and his associates do not differ sharply from those of Shock, although the former were derived in Colorado, the latter in California. The climate of Minnesota the year round can not differ from that of both of these regions more than they differ from one another. The source of the discrepancies must be sought in the selection of the material used and the conditions under which the subjects were studied.

Race and climate. These standards correctly apply only to Caucasians in temperate climates. Racial distinctions have been noted in Mayas of Yucatan, women of South India, Eskimos, Araucanian Mapuches, Australian aborigines,

Jamaican negroes, etc. There is still some uncertainty about the Chinese and Japanese. Some, but not all, of these distinctions may be due to climate and habits; the metabolism of Caucasians becomes slightly reduced after a sojourn in the tropics (93). The subject has been reviewed by Benedict (30).

Season. There is some evidence that the metabolism is slightly higher in cold weather than in hot (110). Gustafson and Benedict (150) found that the basal metabolism of 20 normal female college students during winter months was 5 to 10 per cent lower than it was in the spring and summer. This difference, they believe, may be related not to temperature variations but to other seasonal factors, possibly variations in sunlight.

THE EFFECT OF FOOD ON METABOLISM

Most investigators have detected no characteristic variations of basal metabolism which can be referred to the influence of the previous dietary regime. Krogh and Lindhard (196, 197) claim that after a low protein diet the basal metabolism becomes definitely lowered. They also conclude that it is lowest when the respiratory quotient lies between 0.8 and 0.9, that is, when the subject has been receiving a diet rich in carbohydrate. After a high protein diet, according to Wishart (378, 379) the basal metabolism rises.

Effect on rate of total metabolism, specific dynamic action (110, 219, 221). Immediately after a mixed meal the glucose, urea, amino acids and lipids of the blood rise, an indication that the disposal of the digestion products does not keep pace with their absorption from the alimentary canal. By respiratory or direct calorimetry the heat production may be shown to rise at the same time.

This rise in heat production, which has been called "the specific dynamic action" of foods, varies with the nature of the food given. It is greatest for protein, less for carbohydrate and least for fat. Of the fuel value of fat about 2.5 per cent, of carbohydrate about 5 per cent and of protein more than 10 per cent is used to meet the specific dynamic action of the food itself, and has been called by Benedict and Carpenter "the cost of digestion." In calculating dietary requirements DuBois (110) recommends that 5 to 6 per cent of the total food calories must be added for an individual on a mixed maintenance diet; 2 to 5 per cent if the diet is below his caloric needs; 6 to 8 per cent if the diet is liberal and if more than 12 per cent of the calories are derived from protein. For extremely high protein diets the allowance must be two or three times as large as this.

For general discussions of the nature and causes of the specific dynamic action of foods the reader is referred to reviews by Lusk (223) and by Wilhelmj (375). It is not merely an expression of the energy consumed in the activities of digestion, since it can be elicited by certain food products whether they are given orally or intravenously (269, 371). Among these are amino acids (220, 296, 297). Rapport and Beard (297) have estimated that the total specific

dynamic action of a given amount of a pure protein (casein or gelatin) is of the order of magnitude of the sum of the effects of the individual amino acids of which the protein is composed. Wilhelmj (375) has calculated that the specific dynamic action of simple amino acids is a linear function of the molecular equivalents of amino acid metabolized.[7] It appears most probable that specific dynamic action is the result of heat liberated by chemical reactions involved in or stimulated by the intermediary metabolism of food products. In the case of amino acids Lusk identified it with the metabolism of the deaminized product, especially its conversion to glucose. More recent evidence (375) indicates that the process of deaminization is more important.

The energy evoked by the specific dynamic action of the foodstuffs can not be utilized for the conduct of work. This was first demonstrated by Rubner and confirmed by Anderson and Lusk and Benedict and Murschelhauser (see Lusk (219)). They showed that if a subject exercised in the fasting condition and after the ingestion of meat, the increment produced by exercise was the same; but, after meat, the total metabolism was greater, the difference being equal to the specific dynamic action of the protein. Dock (100) compared the oxygen consumption of various organs of rats which had received a diet containing 74 per cent casein with that of rats which had subsisted on ordinary diets. Of the organs examined only the livers of the rats on high protein diets consumed significantly more oxygen than the controls did. From these experiments Dock concluded that the liver was the chief or sole site of the metabolic processes responsible for the specific dynamic action of protein.

Specific dynamic action varies not only with the nature of the food, but also with the condition of the subject fed. It has been claimed (368), probably erroneously (112), that it is reduced in patients with endogenous obesity. There is evidence that protein has far less effect after starvation or protein deprivation. McCann (242) found the specific dynamic action of protein greatly reduced after an eight day fast. In this case the nitrogen excretion was not augmented by the ingestion of 350 grams of meat at a single meal. Evidence of a similar nature is found in the complete absence of specific dynamic action after hepatectomy (229). McCann's experiment is not necessarily at variance with those of Wilhelmj, Bollman and Mann (376) in which specific dynamic action was demonstrated in the fasting dog after intravenous injection of amino acids.

Earlier claims (129) that the thyroid, pituitary and adrenal glands influence specific dynamic action have not been substantiated (107, 126, 135, 262, 375).

Effects of different foods on respiratory quotients. Besides its effect on heat production each food also has a characteristic influence upon the respiratory

[7] Some confusion has arisen from failure to recognize this point. Specific dynamic actions should be expressed and can only be compared in terms that relate them to the quantity of a given substance metabolized, not to the level of antecedent metabolism (375).

quotient. After ingestion of *carbohydrate* the R.Q. usually rises to an extent which depends upon the amount and nature of the carbohydrate consumed, because carbohydrate utilization begins to predominate over combustion of fat and protein. Carbohydrate is utilized in three ways, which may be represented in the following manner:

1. Synthesis to glycogen. $nC_6H_{12}O_6 = (C_6H_{10}O_5)_n + nH_2O$. Does not affect R.Q.

2. Combustion. $C_6H_{12}O_6 + 6\,O_2 = 6\,CO_2 + 6\,H_2O$. Has R.Q. of 1.00 and raises the R.Q. towards that level.

3. Fatty acid formation. $3\,C_6H_{12}O_6 = C_{18}H_{36}O_2 + 8\,O_2$. Tends to raise R.Q. above 1.00, by furnishing endogenous O_2 and thereby lowering O_2 intake. (See p. 17.)

It was pointed out above, in relation to "The conversion of carbohydrate to fat," that the R.Q. indicates the end result of combustion of carbohydrate, conversion of carbohydrate to fat and combustion of fat, in terms of the net decrease of carbohydrate and fat in the body. Consequently, if reactions 1, 2 and 3 and fat combustion alone affected the calculations, glycogen formation could be estimated as the difference between carbohydrate absorbed and carbohydrate burned (or excreted), the relatively small amount of free glucose in the body remaining constant.

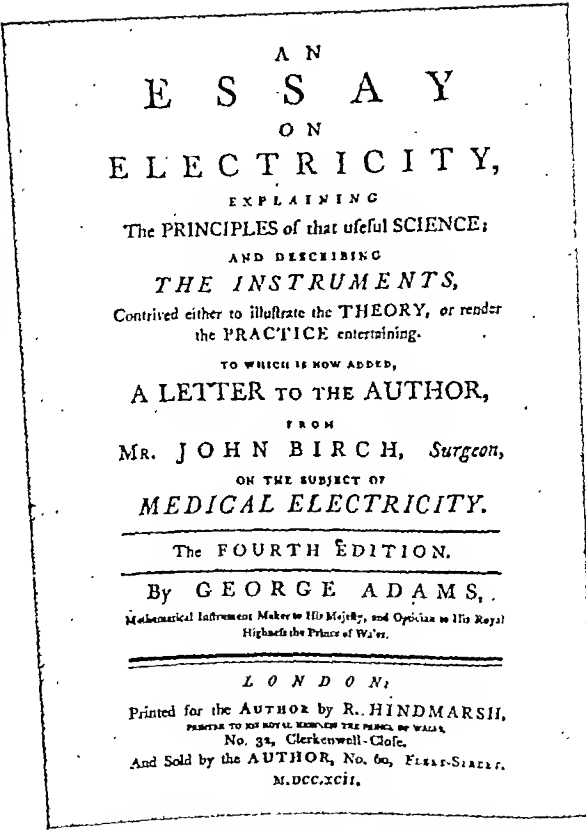
Such calculations have been made and from them deductions have been drawn concerning the rate and mode of utilization of various carbohydrates. For example, Higgins (164), by precise measurements of the respiratory exchange in periods of four minutes each after the ingestion of 100-gram doses of different sugars found that, while glucose and maltose caused the R.Q. to rise relatively slowly during one and one-half hours to 0.90 to 0.97, sucrose and fructose raised it in fifteen minutes to 1.10 to 1.15. This was interpreted to mean that levulose and sucrose were to a large extent changed to fat (75, 164). Campbell and Maltby (61), however, have shown that when fructose or cane sugar is metabolized, lactic acid is formed in sufficient quantities to decompose bicarbonate in the body. Excretion of the resultant CO_2 increases the R.Q. in precisely the same manner that it does when lactic acid formed during exercise decomposes bicarbonate. This introduces a fourth reaction that must be taken into consideration:

4. $C_6H_{12}O_6$ (fructose) $= 2\,C_3H_6O_3$ (lactic acid)

$$H(C_3H_5O_3) + BHCO_3 = B(C_3H_5O_3) + H_2O + CO_2$$

Obviously, under such conditions conclusions concerning the fate of carbohydrate can be drawn from changes of R.Q. alone only if correction could be made for CO_2 released by reaction 4. It has been pointed out above that there is no formula by which such correction can be made with accuracy.

Carpenter and Lee (72), on the basis of simultaneous observations of R.Q.



AN

ESSAY

ON

ELECTRICITY,

EXPLAINING

The PRINCIPLES of that uſeful SCIENCE;

AND DESCRIBING

THE INSTRUMENTS,

Contrived either to illuſtrate the THEORY, or render the PRACTICE entertaining.

TO WHICH IS NOW ADDED,

A LETTER TO THE AUTHOR,

FROM

MR. JOHN BIRCH, *Surgeon,*

ON THE SUBJECT OF

MEDICAL ELECTRICITY.

The FOURTH EDITION.

By GEORGE ADAMS,

Mathematical Inſtrument Maker to His Majeſty, and Optician to His Royal Highneſs the Prince of Wales.

LONDON:

Printed for the AUTHOR by R. HINDMARSH,
PRINTER TO HIS ROYAL HIGHNESS THE PRINCE OF WALES,
No. 32, Clerkenwell-Cloſe.
And Sold by the AUTHOR, No. 60, FLEET-STREET.
M.DCC.XCII.

FIG. 9.—Facsimile of title page of George Adams' essay, London, 1792.

The most careful and scientific clinical observer of this period was John Birch (1745–1815), surgeon to the Prince of Wales and attending surgeon to St. Thomas's Hospital. About 1780, he began to test the efficacy of static electricity on patients presenting various diseases. In this work he had the assent and approbation of some of the ablest practitioners of the day, including Drs. Heberden, Sr.[1] (1710–1801) and Warren[2] (1731–1797), Mr. Else, Mr. John Hunter[3] (1728–1793), and Mr. Gunning[4] (d. 1798). During this period he endeavored to establish a regular branch of electrical practice and teaching at St. Thomas's Hospital. This was not accomplished until about 1799, owing "to the short time of residence of the students in London." In the preface to his interesting *Essay on the Medical Application of Electricity*[5] (Fig. 11), Birch says:

"Experience is the test by which we judge of a proposition; and repeated facts, well authenticated, carry conviction with them. It is now upwards of twenty years that I have unremittingly pursued this point of study. . . .

"An operation is often more admired than a cure by any other means, as it is at once splendid and lucrative. I am therefore obliged to limit the hospital practice to particular cases, which I attend myself, because I can so seldom prevail on a young student to take the necessary pains which are required to become an able electrician."

That Birch did not consider electricity a universal panacea is clearly set forth in the following paragraph:

"To consider electricity as an universal remedy, is as absurd, as to deny it a place in the science of surgery. Some of the following cases will prove it is a bold experiment, which may be safely tried; and what cannot fail to raise our admiration is, that so mighty a power, capable of extinguishing life at a stroke, may with discretion, be passed through the tender fabric of the brain."

Birch sets forth his conclusions—based upon a long clinical experience:

"It was the usage of St. Thomas's hospital to admit nothing new into its practice until seven years experience had given it validity: I have had three times seven years test of the pre-eminent power of electricity, and am proud

---

[1] William Heberden, Sr., was one of the most eminent physicians of the eighteenth century, being the first to publish a description of angina pectoris.

[2] Richard Warren, physician to Princess Amelia, later to George III (1762) and the Prince of Wales (1787); physician to the Middlesex Hospital from 1756 to 1758, and to St. George's from 1760 to 1766.

[3] John Hunter, comparative anatomist, physiologist and surgeon, founded the natural history museum which bears his name. He began his medical career as anatomical assistant to his brother William. He was elected a fellow of the Royal Society in 1767.

[4] John Gunning was assistant surgeon and later surgeon to St. George's Hospital from 1760 to 1798. He was appointed the first professor of surgery in that institution in 1790.

[5] London, 1802

FIG. 10.—John Birch (1745–1815). From a mezzotint in the collection in the Surgeon-General's Library, Washington.

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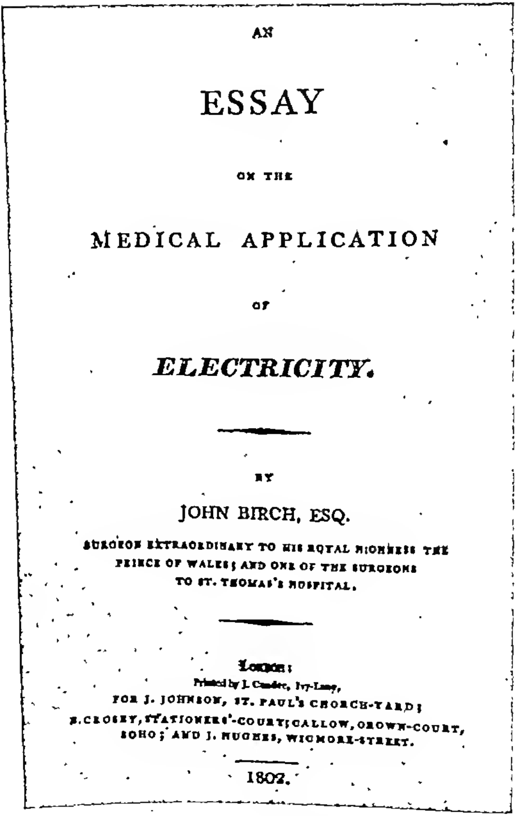

AN

ESSAY

ON THE

MEDICAL APPLICATION

OF

ELECTRICITY.

BY

JOHN BIRCH, ESQ.

SURGEON EXTRAORDINARY TO HIS ROYAL HIGHNESS THE PRINCE OF WALES; AND ONE OF THE SURGEONS TO ST. THOMAS'S HOSPITAL.

LONDON:
Printed by J. Cundee, Ivy-Lane,
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SOHO; AND J. HUGHES, WIGMORE-STREET.

1802.

FIG. 11.—Facsimile of title page of Birch's essay, London, 1802.

FIG. 12.—Luigi Galvani (1737–1798). From a lithograph by Engelmann.

to own, that without this aid I must have been obliged to perform many more operations."

Benjamin Golding[1] (1793–1863) in his *Historical Account of the Origin and Progress of St. Thomas's Hospital, Southwark*,[2] praises John Birch's work in the electrical department:

"Underneath the Dresser's room is an apartment which, we have been informed, was originally built for the reception of an electrical apparatus, and for the extensive administration of the electric fluid, under its various forms, to numerous diseases, in compliance with the wish of one of the surgeons to the hospital, the late Mr. Birch, who long afforded to that department of the curative art his steady support, and continued to sanction its employment till his death, when electricity lost one of its most scientific patrons in the faculty, and thence became disused at St. Thomas's Hospital."

Approximately at the end of the eighteenth century, there emanated from Italy a series of observations that developed into a recognition of the constant current with numerous devices for its production. Electrical science was at the dawn of a new era, and the experiments of workers in the early period of the nineteenth century inaugurated the vast electrical developments to which present day civilization owes so much. First among these observers must be mentioned Luigi Galvani (1737–1798), professor of anatomy of the University of Bologna, who made numerous observations on the contraction of the muscles of frogs through the agency of electricity. There appears to be ample evidence that many of Galvani's electrical experiments were performed before the year 1780. On one occasion, when the dissection of a frog was taking place in close proximity to a charged electrical machine and the dissecting scapel touched the muscles, they were noticed to contract violently. This observation was made by Madame Galvani and communicated to her husband, who repeated the experiment and later observed that the same effect could be obtained outside the influence of the electrical machine providing a circuit was formed of two dissimilar metals. The manuscript giving the results of Galvani's experiments upon the electricity of metals is dated September 20, 1786, and the results of his observations were first published under the title *Aloysii Galvani de Viribus Electricitatis in Motu Musculari. Commentarius: cum Aldini Dissertatione et Notis*[3] which appeared during 1791–1792. In this treatise he expresses the belief that the tissues of

[1] Benjamin Golding entered as a student at St. Thomas's Hospital in 1813, and received his M.D. from St. Andrews in 1823. He was elected physician to the West London Infirmary, which, mainly through his efforts, became the Charing Cross Hospital. He took an active interest in the hospital and the medical school, remaining a director until 1862. His account of this hospital, *The Origin, Plan and Operations of the Charing Cross Hospital, London*, was published posthumously in 1867.

[2] London, 1819.

[3] Published in the seventh volume of the memoirs of the Institute of Sciences at Bologna.

animals possess a peculiar kind of electricity, by means of which the power of contraction is communicated through muscles and nerves. In the preface of this work Galvani states that he has undertaken the arduous task of preparing his book and of making his numerous experiments with a view of pointing the way to some practical applications of electricity to the treatment of disease. Carpue summarizes Galvani's principal experiment as follows: [1]

"If you lay bare the sciatic nerve of a frog, and take off the integuments, then place the nerve on a plate of zinc, and a muscle on a plate of gold, and connect these metals by means of any conducting substance, contractions are produced; but if non-conductors are used to connect the metals, contractions are not excited."

The experiments of Galvani were received with strong popular, as well as scientific, approval. It was urged that here was positive proof that animals, in the intricacies of their muscles, nerves and vital organs, generated electricity. As we shall note, this conclusion was vigorously opposed by Volta and led to a prolonged controversy. In support of Galvani's doctrine the evidence of the power of the Gymnotus electricus to produce shocks was recalled. In the *Transactions of the Philosophical Society* for 1775 [2] there had appeared a letter from Dr. Alexander Garden [3] (1730?–1791), a physician of Charleston, South Carolina, to his friend John Ellis [4] (1710?–1776) under date of August 14, 1774, describing this curious fish, popularly called the "electric eel." It seems that several of these fish had been brought to Charleston from a river in Surinam,[5] and Garden had an opportunity of examining them superficially, but was unable to secure a dead fish for purposes of dissection. He writes:

"There are five of these fishes now here, from two feet in length to three feet eight inches. . . . The person who owns them rates them at too high a

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[1] *An Introduction to Electricity and Galvanism*. London, 1803.

[2] Vol. LXV, p. 102.

[3] Alexander Garden studied at Edinburgh and Aberdeen. He located in Charleston, South Carolina, where he became well known as a physician and botanist. He published in 1764 *An Account of the Medical Properties of Pink-Root*. Linnaeus (1707–1778) named the "gardenia" in his honor. He was a loyalist and at the outbreak of the Revolutionary War left America for England. His only son, Alexander, served during the Revolution as an officer in Lee's Legion. While in Charleston, Dr. Garden had among his students William Charles Wells (1757–1817), who later received the Rumford medal for his *Essay on Dew* (1814). At one time Dr. Garden was vice president of the Royal Society.

[4] John Ellis was born in Ireland. Linnaeus termed him a "bright star of natural history and the main support of natural history in England." In 1764 he was appointed agent for West Florida. This brought him many correspondents, and he used his opportunities to import various American seeds. In 1754 he became a fellow of the Royal Society, and in the following year established his reputation as one of the most acute observers of his time by the publication of *An Essay towards the Natural History of the Corallines*. In 1768 the Copley medal was awarded to Ellis for these researches. Linnaeus named a group of plants *Ellisia* in his honor.

[5] Dutch Guiana.

ARTHROPLASTY.—Arthroplasty performed on a joint which is ankylosed as the result of an old injury is a reconstructive operation that is growing in favor. It is considered here under the arthritic-periarthritic conditions because usually fascial transplants or other soft tissues play a part in the operation. I have obtained the best results in arthroplasties on the following joints in the order in which they are mentioned.

Ankylosis of the Temporomaxillary Joint.—One case was the result of a blow on the chin; one case of a fracture through the neck of the mandible; and one case of severe infection from a peritonsillar

FIG. 6A.—Myositis ossificans developing in the triceps tendon in a case of fractured olecranon. The bony deposits pressed upon the ulnar nerve, causing paresis and pain. This roentgenogram also shows the tip of the fractured olecranon missing, which was removed at operation eight months prior to this film.

A case which I had some five years ago furnishes one of the best examples of this condition:

CASE I.—R. B. suffered a skull fracture and was in a comatose condition for 16 days. When he regained consciousness, he complained of pain in the neck. Four weeks passed before restricted movements of the right arm were noticed. I saw the patient 12 weeks after the accident. He had recovered from the skull fracture but complained of pain in the upper cervical region and inability completely to abduct or raise his arm. Weakness in the shoulder muscles was the chief complaint. Examination showed that the head was held slightly to the right side and that a mild condition of wryneck was present. The supraspinatus and deltoid muscles were atrophied as compared with their fellows and the right shoulder was smaller and somewhat dropped. Examinations of radiograms of the cervical region were apparently negative. These were then submitted to Dr. Hollis Potter, who pointed out a slight discrepancy in the relationship of the first and second cervical vertebrae. The atlas gave the impression of lying slightly forward in the lateral view.

With this slight subluxation of the first cervical vertebra as a possible explanation of the patient's condition, he was sent to the hospital and traction was applied to his head. This relieved the pain which, however, recurred as soon as traction was discontinued. The patient was then anesthetized and, with my hands placed on either side of his head, traction was made and the wryneck overcome by straightening the head; then, with traction maintained, the head was gently but forcibly bent forward (a movement which was impossible for the patient to perform). Almost simultaneously with the beginning of this forward flexion of the head there was a definite snap in the neck which could both be felt by the operator and heard by several who were observing the procedure. Immediately resistance to movements of the head in all directions ceased.

When the patient awoke from his gas anesthesia, he could move his head, although there was some pain. The next day he stated that the pain in his neck had ceased. He left the hospital two days later, free of wryneck and pain and with normal head movements. Within two weeks he was using his right shoulder muscles normally. The atrophy disappeared within two months.

Careful study of many of these obscure joint conditions will reveal slight subluxations, especially in finger joints, or slight adhesions within the joint, especially in the shoulder or knee joints, or a localized area of tenseness and swelling in a muscle over the joint. Often the condition results from a contusion, or a hematoma, with fibrous organization. These are the conditions which yield to manipulative surgery and in which manipulation is definitely indicated. Seldom, if ever, should an anesthetic be given in these cases. It is better to repeat manipulations several times than to run the risk of increasing the joint difficulty.

Forced manipulation of definitely ankylosed joints, either from fibrous or bony causes, under gas anesthesia, is never indicated. Such manipulation usually results in duplicating the original trauma, is

physical therapy are as important as the operation in the reëstablishment of joint function. Sometimes a small amount of lateral movement in the reformed joint follows, but the muscles of the arm and about the elbow soon learn to control this.

Shoulder Joint.—Arthroplasty of the shoulder joint is successful provided the foreshortening of the capsule, ligaments, and muscles can be overcome. Great effort should be expended in attempting to abduct and elevate the arm before resorting to this operation. In many cases good function will thus be reëstablished, obviating the need of operation. I have removed the excessive callus, a portion of the head, and the badly displaced fragments in several cases, and have followed the operation by traction and physical therapy, with some excellent results in functional restoration in this joint. Complete arthroplasty is seldom indicated.

Knee Joint.—Arthroplasty of the knee joint is indicated in selected cases. In severe fractures into this joint, with bony ankylosis which has obliterated all signs of the joint surfaces and with the leg in fairly good position, it is never indicated. Stability of the knee joint is the first consideration, and the risk of giving a flail joint in such cases must be borne in mind. In cases of bad displacement, such as a marked flexion of the lower leg with a stiff knee joint, especially in younger individuals, the operation may be performed.

Hip Joint.—Arthroplasty of the hip joint is occasionally indicated, and here again, in selected cases, it is successful. The reconstructive operation of Albee gives promise of success. The effort to remold the acetabulum and the head of the femur followed by early physical therapy has been partially successful in two of my cases.

Manipulative Surgery.—This is a term employed by Dr. A. G. Trumbull Fisher, of England, as the title of a small book which deals with obscure joint and skeletal conditions so frequently overlooked or considered as inconsequential by many surgeons. It is a book which should be in every doctor's library.

Bone setters, osteopaths, and similar cultists have been successful where the more learned men of our profession have failed because they have learned the value of certain manipulative procedures. Trained physicians have this advantage over these others, namely, that they know when not to manipulate because of the dire results which may follow such a method.

Subluxations, or incomplete dislocations of certain joints, are far more common than is generally realized. Often these partial dislocations are so slight that they are unobserved by a study of the roentgenogram. Nevertheless, they cause more or less continuous pain or pain on certain movements, slight swelling, and restricted movement of the joint. When occurring in a vertebral joint, the pain is often referred along the course of a nerve, and even atrophy and weakness of the muscles supplied by a nerve may be observed.

tween the teeth several times a day. The size of this cork should be enlarged at least every other day in order to increase the range of motion.

Heat, usually in the form of large hot fomentations, followed by gentle massage, daily increased in force, should precede these efforts of prying the teeth apart and inserting the cork.

Restoration of Function.—When a partial ankylosis has developed, especially due to fibrosis of the soft tissues, heat, massage, and regular mouth exercises should be instituted several times a day. Here again the cork can be used to maintain every gain in motion. The chewing of wax or two or three sticks of chewing gum offers excellent means of exercising these joints.

Ankylosis is usually divided into an extra-articular fibrous type and a bony intra-articular type. The technic of operation was best described by Murphy, and his articles on the subject should be studied before attempting the procedure. In brief, it consists of exposure of the joint; removal of the neck, or sometimes of the head and neck, of the mandible; swinging a pedicle flap of fascia from the temporal region and placing it between the joint and the end of the resected mandible; and closure and immediate traction by means of a cork or gag placed between the teeth of the affected side. There are many cases of ankylosis of the jaw on which this operation can be performed successfully.

Heat, massage and exercise, as described above, must start early following this operation and must be persisted in until the greatest possible function is restored.

Sternoclavicular Joint

Treatment.—Maintenance of Reduction.—Partial or complete dislocations of this joint, although rare, are the commonest form of injury occurring here. Reduction of the dislocation is usually easy, but maintenance of this reduction is often extremely difficult. Forcefully pushing the shoulder of the affected side backward and upward, at the same time pushing inward on the head of the clavicle, reduces this dislocation. A pad of felt placed over the joint and held in position by tight strapping with moleskin adhesive while the shoulder of the affected side is held forward and erect by strapping will keep this joint in position. Some have advocated holding the arm raised until it is in contact with the cheek, with the forearm flexed over the head as a means of keeping the reduction in place. The arm must be maintained in this position for approximately two weeks. When this method is used, massage of the shoulder joint and elbow joint and muscle exercises should be instituted to prevent loss of function during this period.

followed by lacerations and hemorrhage in and about the joint, and on healing leaves even a more marked aftermath than previously existed. These are the cases that require prolonged and painstaking physical therapy to restore function.

Perhaps occasionally there may be a case of short duration in which the beginning ankylosis is definitely fibrous and in which the patient will not allow manipulation, where one is justified in giving an anesthetic and attempting gentle, gradual, but forceful manipulation. Good results have followed such a procedure, but one must be adept in selecting these rare cases or he will damage many joints in trying to improve a few.

When in doubt, use the slower, surer methods offered by physical therapy.

SPECIAL JOINTS

Since physical therapy procedures in acute joint injuries have been considered at length by Moorhead and Herring (Vol. II), the discussion here will be limited to those measures necessary to prevent deformity or to overcome *causes of dysfunction* following joint injuries.

Temporomaxillary Joint

Joint functions in a temporomaxillary joint are threatened in the presence of certain infections in or near this joint; in the case of severe injuries to the soft tissues about the joint; and in certain fractures involving a portion of the joint.

Infections.—Localized infections usually resulting in abscess formation, for example, in the wisdom tooth with severe alveolar abscess or extensive peritonsillar abscess, may involve this joint directly or cause such severe scar formation periarticularly as to result in ankylosis. Occasionally a generalized infection, for example, a neisserian infection, may attack this joint, resulting in ankylosis. It is often involved in a generalized arthritis deformans.

Trauma.—Severe blows or falls on the tip of the chin may result in a marked traumatic arthritis in one or both temporomaxillary joints, followed by bony proliferation with ankylosis. Severe fractures of the coronoid or condyloid processes, with such marked displacement that ankylosis of the healed fracture will result, are not uncommon.

Treatment.—Prevention of Ankylosis.—In any of the above conditions the surgeon's first efforts must be directed toward the prevention of this deformity. Movements of the mouth are encouraged. Daily the teeth should be pried apart and a small cork inserted be-

In treating this dislocation, one should bear in mind the danger of loss of function by the prolonged immobilization so necessary to securing a healing in this joint. Even with prolonged immobilization the results are often disappointing, the dislocation recurring all too frequently.

Use of Splint.—In an incomplete dislocation, a peach-board triangular splint, giving approximately a 45° abduction of the arm, is placed in the carefully padded axilla. Pressure is made downward upon the dislocated clavicle and at the same time upward and backward pressure is made upon the shoulder until the reduction is complete. A felt pad is then placed over the acromioclavicular joint, and a firm strap of moleskin adhesive is placed around the shoulder over the pad and through the triangular peach-board splint, binding the angle of this splint tightly into the axilla. The triangular splint is held firmly to the side of the body by moleskin strapping and the arm is likewise strapped to the other leg of the triangle. The elbow is left free for movement. After two weeks the strappings are removed, and with the shoulder held in an elevated and backward position, massage is given to the arm and shoulder girdle. The splint is then reapplied. The patient is asked to report every third day for this massage treatment. After four weeks very slight passive and active motion can be started in the shoulder joint. The elbow is left free from the splint and is exercised daily by the patient. After six to eight weeks the splint can be left off and heat, massage, and exercise applied to the shoulder girdle, with a view of getting complete abduction and elevation of the arm.

Operation.—In the case of complete dislocation, especially in working men, it is far better to operate immediately upon this dislocated joint than to attempt the prolonged immobilization necessary to secure a questionable result.

Many operative procedures have been advocated for this dislocation. The best method consists of drilling holes between the acromion and clavicle suturing these two directly together, combined with a ligamentoplasty, closing the ligaments firmly across the joint. Following operative procedure, immobilization upon a triangular peach-board or a wire splint, or the use of a regular airplane splint, is far better than a Velpeau or Sayre dressing. Within two weeks following the operation, the massage and exercise advocated above should be instituted. Usually six weeks of immobilization are sufficient in operative cases.

Shoulder Joint Injuries

In all cases referred to me because of stiff or painful joints following injury, the shoulder joint is by far the most commonly affected, excepting those numerous and aggravating conditions developing about the lumbar and sacro-iliac regions. In taking the history of these cases and

Operative Procedure.—In old dislocations or in dislocations that cannot be overcome by closed treatment, operative procedure is indicated. The joint is opened by a semilunar incision with its base upward. The dislocated head of the clavicle is reduced, followed by the suturing of the torn anterior ligament from the sternal side over to the ligament and periosteum attached to the clavicle. In one case I used a piece of fascia lata transplant to reënforce this joint capsule and in another case I was satisfied with the above operation without the transplant. The latter case was successful, while the former redeveloped a partial dislocation.

Immobilization and Massage.—Immobilization of the shoulder and arm, either in the closed or operative method, lasts from four to six weeks. After the first week of this immobilization, the arm should be carefully abducted and elevated to, or just above, a right angle at least every other day, and the entire arm and shoulder girdle should receive massage in order to prevent contraction of muscles and ligaments and fibrosis, all of which, if allowed to form, will prolong the disability.

Heat.—Physical therapy in this joint is indicated more often in acute arthritic conditions, especially a neisserian infection. Heat, in the form of an infra-red baker or diathermy, will give the greatest relief of pain.

Acromioclavicular Joint

Dislocations and Fractures.—Intra-articular injuries in this joint are rare. Periarticular injuries consist of dislocations, partial or complete, and of fractures into the joint.

The usual dislocation in this joint is a separation between the acromion and clavicle of more than one centimeter and with the clavicle elevated considerably above its normal position—the supra-acromial or upward dislocation. In addition, there are the subacromial dislocation (downward and behind the acromion) and the subcoracoid dislocation (downward and in front of the coracoid process), but these are rare.

Treatment.—Danger of Loss of Function.—The chief point to remember in fractures or dislocations within this joint is the tendency to develop loss of abduction and reaching power and elevation in the arm. This is usually due to prolonged fixation of the shoulder with the arm held in the adducted position or fixed across the chest by a Velpeau bandage. However, the loss of reaching power may be due to an incomplete reduction of this dislocation or to an ankylosis within this joint. In the normal movements of this joint, when the arm reaches an angle of 45° with the vertical axis, the acromion moves forward drawn by the posterior fibers of the deltoid muscle.

In treating this dislocation, one should bear in mind the danger of loss of function by the prolonged immobilization so necessary to securing a healing in this joint. Even with prolonged immobilization the results are often disappointing, the dislocation recurring all too frequently.

USE OF SPLINT.—In an incomplete dislocation, a peach-board triangular splint, giving approximately a 45° abduction of the arm, is placed in the carefully padded axilla. Pressure is made downward upon the dislocated clavicle and at the same time upward and backward pressure is made upon the shoulder until the reduction is complete. A felt pad is then placed over the acromioclavicular joint, and a firm strap of moleskin adhesive is placed around the shoulder over the pad and through the triangular peach-board splint, binding the angle of this splint tightly into the axilla. The triangular splint is held firmly to the side of the body by moleskin strapping and the arm is likewise strapped to the other leg of the triangle. The elbow is left free for movement. After two weeks the strappings are removed, and with the shoulder held in an elevated and backward position, massage is given to the arm and shoulder girdle. The splint is then reapplied. The patient is asked to report every third day for this massage treatment. After four weeks very slight passive and active motion can be started in the shoulder joint. The elbow is left free from the splint and is exercised daily by the patient. After six to eight weeks the splint can be left off and heat, massage, and exercise applied to the shoulder girdle, with a view of getting complete abduction and elevation of the arm.

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SHOULDER JOINT INJURIES

In all cases referred to me because of stiff or painful joints following injury, the shoulder joint is by far the most commonly affected, excepting those numerous and aggravating conditions developing about the lumbar and sacro-iliac regions. In taking the history of these cases and

in studying the early treatment instituted after injury, one is impressed with the fact that in the majority the stiffness is due to misguided treatment. No injury of the upper extremity, except perhaps in children, should be treated with the arm held adducted to the side of the body for any considerable length of time. I have already mentioned the reasons for this, viz., the contraction of the strong group of muscles which are the adductors and the overstretching and atrophy of the weak group of muscles, viz., the abductors, involved in the shoulder-joint movement.

Direct Causes of Loss of Function.—INTRA-ARTICULAR TRAUMA.—*Traumatic arthritis.*—This is the most common direct injury within this joint. It can result from falling upon the extended hand, in which the head of the humerus is forcibly jammed against the glenoid fossa. Early x-rays are usually negative. X-rays taken from three to six

FIG. 7.—Metastatic abscess of the shoulder joint. This patient developed a general septicemia with a purulent hip joint, the result of a middle ear infection. Drainage of the hip joint and shoulder joint resulted in recovery without the development of the usual osteomyelitis.

weeks later will show the arthritic changes, usually proliferative, within the joint. Occasionally this injury is followed by adhesions within the joint which gradually limit the function and cause pain upon movement. This condition is frequently mistaken for subdeltoid bursitis. Fortunately the treatment of both conditions is practically the same. However, failure to recognize the possibility of adhesions forming within the joint has accounted for my failure to secure recovery in one most important case.

TUBERCULOUS ARTHRITIS.—Tuberculous arthritis is not uncommon within the shoulder joint. It may follow a definite history of injury, although injury is not the chief cause of this condition.

SUPPURATIVE ARTHRITIS.—Primary suppurative arthritis of the shoulder joint is comparatively rare. Suppurative arthritis does occur and it is usually an extension of the purulent process from infected axillary glands or, as in one of my cases, from a severe hand infection with no sign of suppuration within the axilla, but with a definite shoulder-joint suppuration. In two recent cases metastatic abscesses formed in the shoulder joints in generalized septicemia (Fig. 7).

SARCOMA.—Sarcoma, especially chondrosarcoma, may develop primarily within the shoulder joint. In two of my cases it followed a history of definite trauma and in one of these it seemed definitely related to the trauma (Fig. 8).

FIG. 8.—Case of sarcoma of the shoulder. Patient gave history of being struck on the shoulder ten days prior to presenting himself for treatment. The tumor was far advanced and undoubtedly of longer duration than ten days.

ARTICULAR-PERIARTICULAR TRAUMAS.—The articular-periarticular traumas which can result in loss of function in the shoulder joint are: Fractures of the anatomic or surgical neck of the humerus, fracture-dislocations of the head of the humerus, fractures of the scapula extending into the glenoid fossa, and dislocations of the head of the humerus with tearing of the capsule.

Bursitis, Tenosynovitis.— Bursitis of the subdeltoid bursa, when this communicates with the joint, and tenosynovitis of the long head of the biceps which communicates with the joint, are a far more frequent cause of shoulder-joint disabilities than are usually recognized (see Fig. 5).

Sprains.—Sprains of the shoulder joint are not commonly diagnosed, but are undoubtedly quite frequent. A sprain with a partial tearing of the ligaments and capsule about this joint is so frequently accompanied by a dislocation or by a bursitis or a tenosynovitis that these latter conditions are usually diagnosed. However, sprains are not at all uncommon. For example, a man may attempt to jump on a fast moving street car with the result that his arm is forcefully jerked forward. I have seen such an accident result in a pure sprain of the shoulder joint. Likewise, I have seen such an accident result in a tearing of the roots of the brachial plexus; in another case, in an anterior dislocation of the shoulder.

Indirect Causes of Loss of Function.—The indirect arthritic-periarthritic injuries which cause loss of shoulder-joint function are:

Pain.—Limitation of motion in this joint due to pain, often results in loss of function. This may follow a sprain, severe axillary infection, and similar causes, the pain causing the patient to hold the arm in a fixed adducted position until the soft tissues about the shoulder joint have become contracted, and results in an adhesive periarthritis and even arthritis. Not infrequently following rather minor injuries in and about the shoulder joint and the upper extremity, the patient is allowed to carry his arm in the position of greatest comfort, that is, in the adduction position or adducted and held in a sling. There is no evidence of shoulder-joint involvement, and usually none is present; yet the physician is surprised after a few weeks to find the typical loss of abduction and elevation function which he so well knows how to avoid in the more severe injuries involving the shoulder or upper extremity.

Fractures.—Fractures in the shaft of the humerus or in some bone of the upper extremity necessitating prolonged fixation may result in loss of function due to long immobilization of the shoulder joint.

I have already referred to the dangers of applying large hot fomentations to the upper extremity for a hand infection with the arm adducted at the side of the body. Likewise I have referred to the danger of binding the arm to the side of the body in breast amputations.

Brachial Plexus Injuries.—Brachial plexus injuries usually result in complete loss of shoulder-joint function with a loose, flail shoulder joint due to atrophy of the muscles and soft tissues protecting this joint.

Infections.—Infections anywhere in the upper extremity or the axilla, or a subpectoral abscess, may extend into and involve the shoulder joint.

Arthritic Periarthritic Ankylosis.—Complete bony ankylosis of the shoulder joint is rare except in cases of tuberculosis of this joint. Occasionally there is bony fusion between the scapula and the head of the humerus and the acromioclavicular joint which may demand an arthroplasty; otherwise arthroplasty in the shoulder joint is exceedingly rare.

Fracture of Tuberosity of Humerus.—*Fracture* of the *greater tuberosity* of the *humerus* with displacement upward of the tuberosity and union in this malposition may result in a partial limitation of motion due to mechanical impingement of the tuberosity under the acromion.

Stiff Joint.—Stiff joint due to involvement of the soft tissues usually follows contraction of the capsule, contraction of the ligaments, or contraction of the strong adductor group of muscles as already referred to in my classification of joint injuries.

Scars.—This stiffness may be caused by accidental or operative scars about the joint, by the fibrous adhesions within the joint following infection or a traumatic arthritis, or by infection within the bursa with adhesions between the bursa and the synovia and adhesions between the synovia and the joint capsule; and, finally, a general fibrosis about the joint may be the cause of the soft tissue ankylosis.

Treatment.—Immobilization.—Whenever feasible (and in the majority of cases it is) all injuries of the upper extremity requiring immobilization, especially in adults, should be treated with the arm held in more than a 45° abduction position. The longer the immobilization, the greater the degree of abduction, and in cases of prolonged immobilization, both right-angle abduction and external rotation of the forearm are indicated. This principle of splinting the upper extremity to avoid soft tissue ankylosis of the shoulder joint is so thoroughly understood by the majority of the profession that it seems needless to emphasize this point so greatly. However, there are a great many physicians still wedded to the Velpeau and similar bandages in fractures of the clavicle, acromioclavicular dislocations, shoul-

der-joint dislocations, sprains of the shoulder joint and similar injuries (Fig. 9). These physicians will secure far better and quicker results with fewer cases of permanent disability if they will adopt this well-proved method of splintage in the abduction position (Fig. 10).

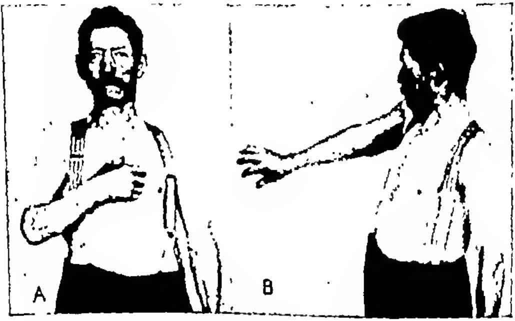

FIG. 9.—*A*, case of dislocated shoulder treated by a Velpeau bandage for three weeks; *B*, same case showing loss of abduction function following treatment in Fig. 9, A.

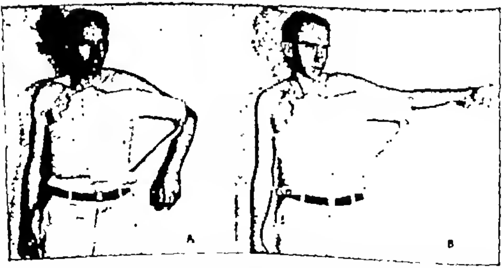

FIG. 10.—*A*, illustrating method of splintage in the abduction position. The roof is taken off the cast changing it into an airplane splint. This allows massage and exercise of the shoulder joint and extremity. *B*, same as Fig. 10, A, showing active exercise of the injured arm.

Thomas Arm Splint.—A Thomas arm splint with traction affords another excellent means of preventing loss of function in injuries of the shoulder joint and humerus. By means of the Thomas arm splint, right angle, or greater, abduction can easily be obtained. By the use of pulleys, the patient can change the position of the arm frequently. Traction by means of adhesive or moleskin adhesive strips applied to the upper arm and attached by means of a guide either to the lower end of the Thomas splint or to weights which run through a pulley inserted to the end of the splint is the commonest form of traction used. The mistake is frequently made of applying these traction strips across the elbow and down to the forearm. The immobilized elbow very early develops stiffness and more physical therapy treatment is often

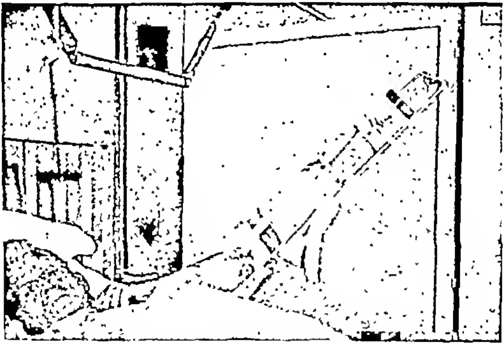

FIG. 11.—Fracture of surgical neck of the humerus suspended in a Thomas arm splint with the arm in the abduction position. The adhesive strips for traction are applied to the upper arm, leaving the elbow free for exercise.

required to restore function in the elbow than in the injured shoulder joint. Therefore these traction strips should be attached only to the upper arm, leaving the elbow free for exercise (Fig. 11). Skeletal traction by means of either a caliper or a wire passed through the lower end of the humerus offers one of the best means of traction, especially in fractures. Jones' splints and other forms of traction splints may be utilized, especially for ambulatory treatment.

Plaster Cast.—In many fractures in this region a plaster cast is indicated. The best plaster cast to use is the airplane type (see Fig. 10).

The fracture is reduced and held in position by an assistant. An undershirt or a woolen bathing suit or even sheet wadding is placed about the body of the patient and around the injured arm, which is held at right-angle abduction. Two or three layers of plaster are now applied around the arm, shoulder, and body down to the waist. A triangular brace, usually made of steel or wire, is now placed next to the plaster with one leg of the triangle against the plaster at the side of the body, one leg on the under surface of the arm down to the elbow, and the long leg of the triangle extending from the elbow to the lower end of the strip along the body. This acts as a brace to hold the arm stabilized in the abduction position. Plaster is now placed around the steel triangle and the arm, shoulder, and body until a firm cast is applied. With only a few exceptions, the roof of this cast—that is, the portion on the upper half of the arm and shoulder—should be removed within two weeks. This leaves at least half the arm exposed for heat and massage. In certain cases the arm is externally rotated, and in this event the forearm must be protected by an additional platform. As a rule, the forearm is not encased in the plaster; thus the elbow is left free for exercise. After four weeks the arm can be elevated from this plaster gutter or splint sufficiently to allow massage of the under surface and assisted active exercise of the shoulder joint. In the majority of fractures, within six weeks almost complete elevation of the arm is obtained. In from six to eight weeks this plaster cast or splint is completely removed. At first the patient will not adduct his arm completely to the side of his body, but gravity alone soon overcomes this difficulty.

Physical Therapy.—Heat, massage, and early active exercise (not only of the shoulder joint, but of every joint in the upper extremity, including the scapula), and early contraction and relaxation exercises of the muscles, followed shortly by assisted active and later by active exercises, are vitally important in the prevention of loss of function in all injuries where splintage or a plaster cast is indicated.

RECENT DISLOCATIONS OF SHOULDER JOINT

Whatever method is adopted, daily attention must be given to joint movement, muscle exercises, and the proper position of the extremity to prevent stiffness. For example, I no longer bind the arm to the side of the body in shoulder-joint dislocations. If fixation seems necessary, I place the arm at rest on a Crane-Savanay airplane splint, or make a right-angle triangle out of light boards held at their angles by adhesive plaster, pad this well and apply it to the side of the body and under the arm, thus immobilizing the latter at a right angle. I see the patient every day for two weeks, giving the shoulder joint massage and exercise and gradually elevating the arm completely above the

head. Such a case can usually be discharged as cured at the end of three weeks.

Wasting of the muscles about the joint frequently follows shoulder dislocation. Massage and active use of the limb are the greatest preventives. This wasting of muscles makes dislocation prone to recur several weeks later. Immediate recurrence by active use is rare.

SPRAINS

A sprain of the shoulder joint of sufficient severity to cause pain on movement and swelling about the shoulder girdle is of sufficient importance to demand careful treatment by any physician. Rest in bed with the arm held at the right-angle abduction position by pulleys or a sandbag and with large hot fomentations about the shoulder girdle with daily massage and light assisted exercises, increasing the range of the movement of the shoulder joint daily, will result in recovery from this condition within two weeks in the majority of cases. Instead of the hot fomentations, an infra-red baker may supply the heat to this joint, or, if available, diathermy will be the best means of supplying heat and relieving the pain, not only in sprained shoulders, but in other sprained joints.

As a rule the majority of patients temporize with this condition, thinking at first that it is not serious. Such a patient carries his arm close to his body, complaining of pain whenever he tries to elevate the arm sufficiently to put on his coat, and does not consult a physician until two or three weeks have elapsed from the time of injury. These patients require more prolonged treatment to overcome the disabling condition than do those who are treated early. The acute symptoms have subsided and it is almost impossible to have such a patient go to bed, although treatment can be carried out far more easily when the patient is at rest. Ambulatory treatment is usually necessary. Some form of airplane splint or a woven-wire triangle splint or a peach-board triangular splint placed along the side of the body and in the axilla in order to hold the arm in the abduction position is necessary. The amount of abduction should be increased every few days until the arm is not only abducted but elevated to more than a right angle. These patients should report to the physical therapy laboratory for treatment. Here heat in the form of infra-red lamps, diathermy, or hot fomentations should be given to the shoulder for at least 30 min., followed by 30 min. of massage, by 30 min. of assisted active exercises, and later by active exercises. If the weather is cold, the arm and shoulder should be wrapped in flannel until the patient reaches home, when heat in the form of a hot water bottle, an electric pad, or an infra-red light should be applied by the patient several times a day, combined with light but ever-increasing exercise.

TRAUMATIC ARTHRITIS

Traumatic arthritis of the shoulder joint is best treated by rest in bed with the arm held in an abduction position with traction applied to separate the joint surfaces, combined with heat, massage, assisted active exercises, and later, active exercises. This treatment must be persisted in until all pain on movements has disappeared and until complete shoulder-joint function has been restored. Failure in this condition, as well as in many other of the less serious conditions about the shoulder joint, is due to loss of interest by the physician and lack of persistence in the physical therapy treatment until the condition is completely cured.

BURSITIS AND TENOSYNOVITIS

Bursitis and tenosynovitis about the shoulder joint are both treated as outlined for the treatment of sprains. Here again the earlier the treatment is instituted for the injury to the bursa or the long head of the biceps, the more rapid will be the recovery. The majority of these patients are seen late. They are comfortable as long as the arm is held idle in the adduction position at the side of the body. It is only when the patient attempts to abduct it more than 30° or when he makes certain movements, such as putting on a coat, that pain and discomfort develop. The time of treatment with recovery is double the length of time elapsing since the injury. Proper splintage in the abduction position to protect the weak group of muscles, with heat, massage, and graduated exercises, is the treatment indicated.

FRACTURE-DISLOCATIONS

Fracture-dislocations of the head of the humerus are extremely difficult problems. Open operation is often necessary and consists of first replacing the dislocated head and then bringing the shaft into proper alignment. To do this, the shaft of the humerus must be brought to or above a right-angle abduction position, for the fractured surface of the head practically always points outward and slightly upward. The arm should be held in this abducted position by an airplane plaster cast, which is changed within two weeks into an airplane plaster splint by removing the roof from the cast.

I have seen one case of a fracture through the surgical neck of the humerus operated on by another surgeon, the shaft brought into apposition with the head, which pointed outward and upward, the fractured portions united by kangaroo gut, the wound closed, and then the arm placed in a cast in an adduction position at the side of the body. This position, of course, immediately pulled the shaft downward and at a right angle to the head. Union occurred in this position, and as a result the patient had a marked limitation of motion.

He could abduct his arm only about 25° and then the callus would impinge under the acromion process and prevent elevation of the arm. The man was allowed an 85 per cent loss of the arm by the Industrial Commission. The case was referred for reconstructive operation. The excessive callus was chiseled away, the point of right-angle union between the head and shaft was chiseled through, and

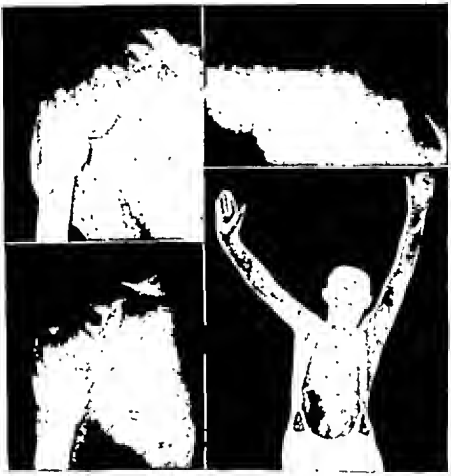
A B C D

FIG. 12.—*A*, fracture of surgical neck of the humerus treated, following operation, with the arm adducted to the side of the body. Union occurred with the shaft at right angles to the head of the humerus, resulting in an 85 per cent loss of function. *B*, same case following operation, with the arm brought into alignment with the head of the humerus. *C*, same case three months later showing complete union. *D*, same case showing amount of function six months after the operation. Two years later there was practically complete function.

then the shaft was brought into an extreme abduction-elevated position in order to align and approximate it to the fractured surface of the head. Union resulted and the patient's disability was reduced to 25 per cent by the Industrial Commission. The patient now has 95 per cent of function in his shoulder joint (Fig. 12). Failure to observe

this principle of abduction and external rotation position in treating fractures in and about the shoulder joint makes reconstructive surgery frequently necessary.

CONTRACTION OF CAPSULE

Contraction of the capsule with firm fibrous adhesions in and about the joint sometimes warrants operative procedure. The shoulder joint is the best example of this condition. The capsule can be well exposed by an incision along the anterior border of the deltoid muscle, and should then be incised in a vertical line, and traction on the arm, with retractors holding the margins of the capsule apart, will reveal the adhesions in the joint. These can be thoroughly removed. The wound in the capsule should not be sutured, as after the fascia and skin are sutured, traction on the arm tends to elongate the capsule. In other words, the vertical incision in the capsule is pulled somewhat into a longitudinal incision. The traction on the arm also separates the joint surfaces, tending to prevent reformation of the adhesions. Again, one must remember to hold such an arm in the abducted and somewhat elevated position and to start early heat, massage, and active motion.

RECURRENT DISLOCATIONS

Recurrent dislocations of the shoulder joint require operative procedure. Fortunately, as a rule these occur in younger individuals. These cases offer possibly the one exception to the abduction immobilization treatment. After one of the several methods is employed for the repair of recurrent dislocation, the arm should be immobilized in an adducted or semiadducted position. Not more than 20° of adduction of the arm should be allowed for a period of two or three months. To safeguard this I have the patient wear a strap around his waist and another strap around his arm just above the elbow. In each of these strap belts is placed a ring, one in the midaxillary line, the other on the inner side of the arm. A short strap approximately six inches long with a snap on either end is snapped into both rings, thus limiting the range of motion to the desired distance. The strap is inserted through small holes cut in the sleeve and coat. Massage and exercise are likewise indicated in these cases.

Arthroplasty.—Arthroplasty of the shoulder joint, as stated above, is rarely indicated. However, I have opened the shoulder joint on several occasions for the purpose of removing excessive callus, a portion of the head of the humerus which was badly displaced, and other fractured fragments in the neighborhood of this joint. The operation is followed by traction and physical therapy with excellent results in functional restoration in the majority of these cases.

Arthrodesis.—Arthrodesis of the shoulder joint is occasionally indicated in brachial plexus paralysis and other conditions resulting in a flail joint. Physical therapy in these cases is indicated to reestablish function in the muscles of the arm and forearm and in the elbow and wrist joint. Occasionally arthrodesis of this joint, accompanied with shortening of the flexor tendons of the forearm or transplantation of the origin of the flexor muscles higher on the humerus and with arthrodesis of the wrist joint to overcome persistent wristdrop, is indicated after brachial plexus trauma. Physical therapy, especially muscle-training exercises and joint reëducation, is indicated in these multiple operations.

Position of Function.—When ankylosis of this joint is inevitable, the best position to give the greatest amount of function will be one of 30° of abduction and slight outward rotation of the arm. In this position the patient, with a normal elbow, can feed himself, comb his hair, tie his tie, etc. Every effort must be made to keep the scapula free and movable. This can be accomplished by daily massage and exercise of the scapula. Scapula movement will add greatly to the amount of function in the ankylosed shoulder joint.

Elbow Joint

Loss of function in the elbow joint following injury is very common. Next to the back and shoulder joints, the elbow deformities are referred for reconstructive surgery most often. Excessive callus following fractures into this joint; proliferation of tags of periosteum; the formation of myositis ossificans; and the general fibrosis of the bursae, synovial sheaths, ligaments, and soft tissues following prolonged fixation, all occur more frequently and more rapidly in the elbow joint than in any other joint of the body.

Prevention of Loss of Function.—Several observations applicable to many injuries of the elbow are necessary to prevent the common causes for deformity in this joint.

Avoidance of Forcible Manipulation.—The elbow tolerates very badly forcible manipulation under anesthesia, the so-called *brisement forcé*. The periosteum in and about this joint tears very easily and is prone to proliferate. A soft tissue ankylosis is rapidly changed into a bony ankylosis by forcible manipulation even when gently applied. Therefore the longer, more tedious method of slow, gradual movement obtained by the various physical therapy maneuvers is far better.

Avoidance of Prolonged Fixation.—Prolonged fixation of the elbow joint is very prone to develop fibrous ankylosis, and if there has been ever so slight a bone injury, bony ankylosis is probable. For this

reason the application of circular plaster casts to the arm so as to include the elbow should be avoided as far as possible. When a cast is necessary, two weeks should be the longest period of leaving it intact, except possibly in tuberculosis of this joint and in certain ununited fractures that will not tolerate mobilization. The cast should be changed into a splint by removing its upper half at the end of two weeks and massage and heat should be started. By the end of three weeks, even in the worst fractures, slight active motion should be begun with the splint removed; it can then be replaced for further wearing if necessary. The surgeon should perform the early mobilization of this joint, trusting the work to the technician only after several instructions in the particular methods to be used have been given in each case.

For the same reason the elbow joint should not be included in adhesive strips applied to the arm for traction. The fixation of the joint by means of traction strips, although not involved in the original injury, soon results in a soft tissue ankylosis (see Fig. 11).

Ceasing Manipulation at Pain Point.—The rule never passively to manipulate a joint beyond the pain point is especially applicable to the elbow. Repeated semiforcible flexions and extensions of the stiff elbow can cause an inflammatory reaction which results in a fibrosis, a myositis ossificans, or excessive bony proliferation in and about the joint.

Rapid Reduction of Swelling.—Excessive swelling about the elbow joint from hemorrhage, transudate, and exudate following severe contusions or crushing injuries is very persistent. Every effort must be made to reduce this swelling rapidly, otherwise fibrosis from this alone will prevent restoration of function no matter how well the joint injury is treated. To be satisfied with the application of ice-bags to such a swelling, awaiting a week or 10 days for it to subside, is not sufficient. The whirlpool bath, light massage, alternating hot and cold baths, and, if necessary, evacuation of the hematoma by aspiration or by a small incision, must all be tried in some of the more obstinate cases.

Early Removal of Fractured Fragments.—The elbow joint tolerates operative procedures better than most joints; therefore fractured fragments which, due to their malposition or to the fact that they are loose in the joint, should be removed early by open operation. Joint mice are rather common in the elbow and can be readily removed. Do not be over-tempted to manipulate the stiff joint under anesthesia while performing these operations. Remove the obstructing cause to joint motion and then depend upon physical therapy to restore function.

Attention to Minor Injuries.—The possibility of a multiplicity of injuries in severe direct trauma to the elbow makes it dangerous for the surgeon to be satisfied with the diagnosis of the major injury and to direct his entire attention to this major condition. Thus the T-fracture through the condyles may be the major injury, but accompanying this there may be a severe traumatic arthritis, a damage to the synovia which extends downward to the synovia surrounding the radio-ulnar articulation, a tearing of the attachments to the humerus of the strong flexor muscles of the forearm, an injury to the olecranon bursa, or a late development of a musculospiral nerve injury with an insidious wristdrop which the surgeon is liable to overlook unless he is watching for every possibility and is not satisfied only with the excellent reduction of the fracture, the major or most apparent injury. Not infrequently with a definite fracture there is a tearing of the joint capsule and a partial dislocation of the head of the radius. This may jump back in place and never be diagnosed until later, when it is found again subluxated.

Care in Taking X-Rays.—X-ray mistakes are not at all uncommon in conditions in and about the elbow. Failure to retake x-ray films results in failure to diagnose the myositis ossificans which is responsible for the loss of function, or of the traumatic arthritis which is slow to show x-ray evidence.

In a recent case the x-ray revealed a fracture of the ulna four inches below the elbow joint. The film first taken included the elbow joint. No pathology was seen in the elbow. After the fracture was reduced and a posterior splint applied, a second x-ray was made. This one did not include the elbow joint. The fracture was well reduced and I was satisfied. After a week the patient was allowed to go to his home in a distant city and his family physician was instructed to remove the splint and give massage every other day and slight but increasing active exercise to the elbow after two weeks. At the end of eight weeks this patient was returned to me because the elbow was stiff. A prominence over the head of the radius made me suspect a dislocation and the x-ray confirmed this diagnosis. We reëxamined our early x-rays and found no evidence of the dislocated head of the radius in the first films, and *the second films had failed to include the elbow.* It is possible that in reducing the fracture we caused a complete dislocation of this radius which had been subluxated and then returned to normal position at the original injury. Failure to include the adjacent joint in the x-ray film will cause one to miss these less apparent injuries.

Treatment.—Acute conditions of this joint and fractures and dislocations are dealt with in other chapters; therefore, emphasis will be given chiefly to the conditions resulting in deformity and loss of function.

TRAUMATIC ARTHRITIS

A fall on the extended hand may result in a traumatic arthritis in this joint as well as in the shoulder joint. All the early symptoms may point to the shoulder and the condition in the elbow may be overlooked until stiffness and pain call one's attention to this latter joint. Late development of arthritis in the elbow following any direct injury is not at all uncommon. This joint is quite prone to develop hypertrophic synovitis or osteochondritis dissecans, the formation of joint mice.

FIG. 13.—Proliferation of periosteum and myositis ossificans resulting in ankylosis of the elbow joint following forceful manipulation under general anesthesia.

A patient presented himself with a swollen, painful elbow which had resulted from falling down stairs the day before. Examination revealed a loose, movable bone at the inner aspect of the joint. He gave a history of a fracture of the lower end of the humerus 10 years previously with a stiff elbow resulting. The x-ray showed the loose fragment to be a joint mouse which had popped out of the joint, and several other similar bodies were present within the joint. There was no evi-

dence of recent fracture. An incision was made over the inner aspect of the elbow and six fairly large joint mice were removed. Almost complete function was restored to this elbow.

Another patient fell on her extended hand and suffered a fracture of the head of the humerus. This was treated excellently by one of my former associates. After six weeks she began to complain of pain and stiffness in the elbow which had not been immobilized during the treatment of her fracture. An x-ray was negative. The physician placed this patient under a general anesthetic and manipulated her elbow. This was followed by a marked reaction. Two months later he referred the patient to me with a completely ankylosed elbow. The x-ray showed a marked proliferation of periosteum and a myositis ossificans. This patient refused operative treatment. Physical therapy offered little hope and she has been permanently crippled in this arm (Fig. 13).

Acute.—The acute arthritis following trauma is often the result of a joint injury plus a metastatic infection from a distant focus. This condition should be recognized early and treated by:

(a) Heat: Hot fomentations, infra-red lamp, an electric baker, or a hot whirlpool bath. Do not let the joint cool off between applications of heat

(b) Massage: Gentle stroking and following always the application of heat

(c) Exercise: Usually active, as the patient will not move the joint beyond the pain point and therefore will do no damage. He should be supervised so that he will exercise the joint several times each day

(d) Splints or casts are not indicated

Chronic.—The chronic arthritis must be treated in a similar manner, but first one must ascertain whether the loss of function is due to bony impairment. Traction is often indicated in these chronic cases but should be removed two or three times each day for active exercise and should not interfere with the application of heat and massage. Splints or casts are never indicated. Joint mice and bony obstructions can readily be removed from the elbow joint.

PURULENT ARTHRITIS

Purulent arthritis is not so common in the elbow as in the shoulder, knee or hip. It is usually due to hemolytic streptococcus or staphylococcus. It may become severely involved following injuries to the forearm with extension of the infection into the elbow especially in a case of gas bacillus—Welch's bacillus infection. I have seen severe abscesses of this joint in two cases of late operation for correction of function. In both of these cases there was slight infection present at the time of the original injury, but these had completely subsided and several weeks had elapsed before operative treatment was attempted. Another case of severe purulent arthritis followed operative treatment of

an osteomyelitis of the distal end of the humerus which resulted from the use of a Lane plate. Drainage by either one or, better, two lateral incisions or by a posterior lateral incision along the olecranon is absolutely necessary. Drainage tubes through the joint are contraindicated. Early movement will tend to keep the incisions open, will stimulate drainage, and will promote maintenance of joint function. Traction is often used to keep the joint surfaces separated but should be released for movement several times each day.

As soon as the acute condition has subsided, great attention must be given to the restoration of function. *Heat* (electric baker or infrared lamp, alternating with hot fomentations); *hydrotherapy* (the whirlpool bath or a local arm bath); *massage* of both the forearm and upper arm and later massage of the joint; and daily increasing *active exercise* are all necessary. It may be advisable to rig up a pulley apparatus with weights which will aid the patient in securing the needed exercise —the pulley attached to the foot of the bed when extension is desired or to the head of the bed for flexion exercises, or both, when flexion and extension exercises are wanted.

DISLOCATIONS OF ELBOW

Dislocations of the elbow are dealt with in another chapter. After the dislocation is reduced, the attention of the surgeon must be directed daily to the restoration of function. After reduction, a posterior splint with the forearm at right-angle flexion is usually applied. If the patient is kept in bed, no splint is necessary. The day following reduction, the splint should be removed by the surgeon who grasps the arm and forearm just above and below the elbow and steadies it while the patient is encouraged to attempt slight active movement. If marked swelling is present after reduction, a large hot fomentation may be used instead of the plaster splint. This can be kept hot by syringing hot water into the dressing at two-hour periods. Each day the joint is protected by the surgeon or a trained assistant while a second assistant or technician massages the arm, elbow, or forearm, and then the patient exercises it. After 10 days such a patient can usually be turned over to a trained technician for heat, massage, and exercise. Usually by the end of three weeks a functional elbow is obtained. This is a marked improvement over three weeks of immobilization in a cast or splint, followed by weeks of physical therapy or home efforts at massage to overcome the stiffness which follows prolonged immobilization. In the elbow it is never wise to attempt to forcibly overcome this stiffness.

FRACTURES OF ELBOW

Fractures are likewise dealt with in another chapter. There are certain fractures, however, in and about the elbow that so invariably

result in loss of joint function unless certain preventive measures are adopted that reference must be made to them.

SUPRACONDYLAR FRACTURE OF HUMERUS

A supracondylar fracture of the humerus in young people may well be treated by the hyperflexion method and left in a cast for two weeks without any dire result to the elbow. In older individuals, however, this hyperflexion method must be handled cautiously. Whenever such a fracture is bandaged with the forearm markedly hyperflexed, a posterior splint should be applied which can readily be removed after the third to the sixth day for massage and very slight but definite joint exercise by the patient. Before giving this massage the surgeon can grasp the forearm, hold it hyperflexed and protect the fracture, and immerse the flexed elbow in a very warm local arm bath.

Daily after this the splint should be removed, and heat, water bath, massage, and slight but increasing active exercise should be instituted. Only general rules can be given and conceivably some of these fractures are so severe that longer time must elapse before this is begun, but it is surprising how early, and how much, flexion and especially rotation of the forearm can be developed in these cases within the first three weeks. Seldom is it necessary to maintain the extreme hyperflexion for more than two weeks. The forearm can then gradually be unflexed and a new splint, if necessary, reapplied at this angle as flexion decreases.

FRACTURE OF HEAD OR NECK OF RADIUS

Fracture of the head or neck of the radius seldom needs immobilization by a plaster splint and never by a plaster cast. In several cases of fracture of the head or neck of the radius without dislocation and only slight displacement of the fragment I have started immediate active motion. A loose cotton padding held in place by a bandage is placed about the elbow for the first week and the patient is encouraged to move the elbow joint and rotate the forearm within this padding and bandage. After a week no dressing is applied and daily treatments of heat, whirlpool bath, massage, and active exercise are given. In between these treatments the patient is encouraged to flex and extend and rotate the forearm but never beyond the pain point. After four weeks, such a patient is given more strenuous exercises to do and the surgeon can prescribe mechanical exercises that more forcibly begin to flex and extend the forearm to, but not beyond, the pain point. Usually complete union and full function have been restored by the end of six weeks.

I can see no reason for splints or casts in the majority of these smaller fractures about the elbow joint. Certainly if a splint is applied, it should be removed often for massage and exercise and should never

be worn for more than two weeks. This applies to linear fractures of the head and neck of the radius, fractures of the coronoid process of the ulna without displacement, and epicondylar fractures with very little displacement.

FRACTURE-DISLOCATION OF HEAD OF RADIUS

Open Operation.—Partial, slight dislocations of the head of the radius can successfully be treated as described above. Complete dislocations following a fracture through the neck of the radius should be treated by *open operation with complete removal of the dislocated head* and suture of the incision without any undue manipulation in the wound (Fig. 14).

I have made an incision and then carefully replaced this dislocated head of the radius and have followed this by careful physical therapy, but within a short time complete bony ankylosis has developed. I have

Fig. 14.—Fracture and complete dislocation of the head of the radius.

reduced the dislocated head without an incision and had the same dire result. This has been the experience of so many surgeons that practically all agree that removal of the dislocated head is the safer procedure. However, some authors still describe the technic of open operation with replacement of the dislocated head. I would advocate removal in all adults. Possibly in children the replacement can be done successfully. In children the partially dislocated fragment can be left *in situ* far safer than in adults.

I have overcome 10 stiff elbows by the late removal of this dislocated head followed by 6 to 15 weeks of physical therapy. I have successfully removed the dislocated head of the radius without the ac-

companying fracture in three cases to relieve stiff elbows. In a fourth case of recurring dislocation of the head of the radius I removed it and within two weeks the patient had full function in the elbow.

Following removal of this dislocated head no splint or cast is necessary. Heat, massage, and active exercise are started at once or at the end of 24 hr. In early cases full restoration of function is usually obtained by the end of 4 weeks. One patient, a brakeman, returned to his work within six weeks. In old cases the physical therapy must be persisted in for a longer period and always until practically complete function is restored.

FRACTURE AND DISPLACEMENT OF CORONOID PROCESS OF ULNA

This is a rare condition, but it occurs oftener than the literature would lead one to believe. It is very easy for this fractured portion of the coronoid to slip into the elbow joint and to act as a definite obstruction to movement. It should always be removed, usually by a lateral approach to the joint. Following removal of this fragment no splint or cast is necessary, but heat, massage, and exercise as already described should be instituted at once.

FRACTURES OF OLECRANON

Many stiff elbows following treatment of this fracture have been referred to me as well as cases of nonunion of the fragments. It is noteworthy that in three cases referred there was more complaint on the part of the patient from the stiff painful shoulder than from the olecranon. In each of these the fractured olecranon with its splint or cast had been carried in a sling without any thought given to the prolonged adduction position of the upper arm and its accompanying contraction of strong adductors and the fibrosis occurring about the capsule and ligaments of this joint.

Closed Reduction.—The usual treatment of a fractured olecranon is closed reduction with the forearm held in an extended position and a posterior splint applied to maintain extension. If too early passive or active movement starts, the fragments will be separated and nonunion often results. Prolonged extension fixation, of more than three weeks in adults, usually means a stiff elbow from fibrous adhesions and contractions and will require weeks and months to overcome. Thus one is often between the devil and the deep sea.

Open Operation.—To overcome this difficulty most surgeons advocate open reduction and suture of the fragments by various methods, especially if there is separation. After this operation, extension fixation is indicated, but passive and active movement can usually start earlier without as great danger of displacement and nonunion.

In four cases of fractured olecranon with the fracture line extending through anywhere from the tip to the middle of the olecranon, I have treated the displaced fractured fragment as advocated for the dislocated head of the radius, viz.: An incision is made directly over the olecranon process, the fascia and tendon of the triceps are exposed and, although these are usually torn, they are carefully preserved and separated from the fractured fragment. The displaced fragment is then completely removed and thrown away. The joint is evacuated of any hematoma that may be present. The tendon of the triceps is then carefully sutured to the attachments of the tendon and the periosteum on the remaining portion of the olecranon process. The fascia is likewise carefully repaired. The skin incision is closed. Catgut is used for the buried sutures and silk for the skin. A loose cotton padding is applied about the wound and held in place by a bandage. No splint or cast is applied. The patient is encouraged to shrug or to tense and relax his muscles and gently move the elbow an inch or two within the loose dressing for the first three days. After the third day the surgeon can remove the dressing, massage the arm and forearm and upper surface of the elbow, and encourage very slight but gentle active motion. This should be repeated daily, and after the tenth day the patient should be encouraged to increase the amount of active motion. At this time the patient can be referred to the technician who is carefully instructed to encourage the patient to perform more and more active movements. Heat, massage, and exercise and, after four weeks, work with tools which will increase flexion and extension should be used daily.

In two of these cases which were old conditions approximately 60 per cent (in one) to 75 per cent (in the other—see Fig. 6a) of function was obtained. In the other two cases which were recent fractures full function was obtained and the patients were back at work, one in six weeks and the other in eight weeks. The latter case returned to me eight months after his operation, complaining of numbness and weakness in the fourth and fifth fingers of the same hand. An x-ray of the elbow revealed three separate fragments of bone growing in the triceps tendon. One of these was near the ulnar notch and was undoubtedly responsible for the ulnar nerve symptoms. A second operation was performed and these fragments of bone, a true myositis ossificans, were removed from the triceps tendon (see Fig. 6b). The patient returned to work in two weeks and his ulnar symptoms have disappeared.

I have found no record of this method in the literature. It seems, in properly selected cases, far preferable to the prolonged treatment which is so often necessary to secure union in these badly displaced olecranon fractures and the further prolonged treatment to overcome the resulting soft-tissue stiffness. One, of course, must be sure that enough of the olecranon process remains to guard against a forward dislocation of the elbow.

HEMO-ARTHROSIS OF ELBOW JOINT

Hemo-arthrosis of the elbow joint frequently follows any of these fractures and other severe crushing wounds of this joint. Aspiration of the joint or an arthrotomy performed to relieve this swelling may be necessary. Frequently the stiff joint and the poor function obtained are due to this hemorrhage, transudate, and exudate, followed by organization and adhesions, rather than to the bony injury. Following the early relief of this hemo-arthrosis, heat, massage, and exercise should start. The joint may refill and, if so, it must again be relieved of this swelling which so easily can destroy function.

CRUSHING INJURIES OF ELBOW JOINT

Crushing injuries of the joint are not uncommon, and in one case, at least six fractures were present in and about the elbow joint. The fracture was badly compounded and became infected. Six fragments of bone were removed from the joint and it was left open to drain. Finally, after three months had elapsed from cessation of drainage, I operated on the patient doing a partial arthroplasty or removing fragments which projected into the joint and interfered with motion. Within a few hours the patient's temperature had risen to 104° F. (40° C.) and he developed a second very serious abscess of this joint (Fig. 15).

The lesson here is that one should delay for several months any secondary operation upon these badly crushed joints if an infection has been present.

It is surprising how badly deformed the elbow joint can appear following some of these crushing injuries and what good results can be obtained if the principles of physical therapy are followed, viz.: Early heat, whirlpool bath, or local arm bath; early massage; early active exercise, gradually increased; persistence in efforts to regain function.

ARTHROPLASTY.—Arthroplasty is indicated in many of the conditions giving bony ankylosis in this joint. It is one of the joints that responds very well to this procedure; but a flail elbow joint can be far more disabling than a stiff elbow at 45° flexion of the forearm. In many cases it is better to consider the latter position as the desideratum rather than to risk an arthroplasty with a flail joint. However, the great majority of cases will give excellent results following arthroplasty.

Following the arthroplasty there should be free flexion and extension of the elbow and rotation of the forearm. A loose dressing of cotton padding is applied and a posterior splint with the forearm at right-angle flexion is placed over this. The loose dressing will allow early shrugging, tensing, and relaxing of the muscles, which should be en-

couraged. After three to four days the splint may be removed by the surgeon and very slight, gentle active exercise allowed for a few moments. This should be repeated daily, but the splint is reapplied after each session and kept on for approximately three weeks. By that time the range of motion of the active exercise has considerably increased. Heat, massage, the whirlpool bath, and exercises by special apparatus are added at the end of three weeks and kept up until practically full-joint motion has been obtained. Success in this arthroplasty, as in all others, depends upon the surgeon's ingenuity in working out methods for starting early heat, massage, and exercise and in daily increasing the dosage and upon his persisting in the same until function is obtained (see Fig. 15).

FIG. 15.—*A*, crushing injury of the elbow with six fractures compounded and severely infected. Figure illustrates the final result following arthroplasty and prolonged physical therapy. *B*, same case as Fig. 15, a.

PERIARTICULAR BONY OBSTRUCTIONS

Extension ankylosis is often due to bony deposits in the olecranon fossa of the humerus. Removal of the mass is necessary. When it is accompanied with irregular bony growths into the joint proper, arthroplasty may be necessary. Rotation of the forearm may be lost due to a fracture-dislocation of the head of the radius, and this must be removed surgically, as already indicated. Bony growth or synostosis may develop between the upper end of the ulna and radius

which must likewise be carefully dissected out and a fascial graft placed between the remaining fragments of the two bones to prevent recurrence. Physical therapy is indicated at once in all these cases.

PERIARTICULAR CONTRACTURES

There are cases which have such marked soft-tissue contractures about the joint that function cannot be restored by physical therapy methods alone. These are the cases in which we are so often tempted to do a *brisement forcé*. The usual form of deformity is stiff elbow in flexion position. When the biceps tendon and the brachialis anticus have become so contracted that they will not yield to physical therapy procedures, operative treatment is indicated. The incision is made over the anterolateral aspect of the elbow along the biceps tendon. The biceps and brachialis anticus muscles are exposed and the dissection is carried downward until the anterior aspect of the capsule and the tendons of these muscles are exposed. The biceps tendon is severed obliquely and the brachialis anticus is dissected from its attachment to the coracoid process. The capsule may have to be cut transversely before extension of the forearm is obtained. Following this operation a posterior splint may be applied or, better, a Thomas arm splint, with forearm traction. The latter allows early massage and the traction can be released twice daily for gentle active exercise which should start the day following the operation. The range of motion must be increased rapidly, but the extension must be maintained for three weeks or more to prevent recurrence of the contractures.

FLAIL ELBOW

Flail elbow, when it follows injury or an arthroplasty, must be protected by a hinged splint or converted into an ankylosis by an *arthrodesis operation*. Physical therapy is indicated here to maintain good muscle tone (Fig. 16).

Position of Function.—When arthrodesis is performed or when ankylosis of the elbow is inevitable, an effort should be made to have the forearm in 45° of flexion and very slightly pronated.

Hand and Wrist

While our interest in this chapter is chiefly related to trauma of the joints, yet it is impossible to consider these separately when it comes to the hand and wrist. So many injuries here involve more than one joint and in addition, nerves, tendons, fascia, and skin, that an article dealing with restoration of function must consider all these possibilities.

Loss of function in the hand can prove more disastrous to the majority of people than any other disabling joint condition. Every injury

couraged. After three to four days the splint may be removed by the surgeon and very slight, gentle active exercise allowed for a few moments. This should be repeated daily, but the splint is reapplied after each session and kept on for approximately three weeks. By that time the range of motion of the active exercise has considerably increased. Heat, massage, the whirlpool bath, and exercises by special apparatus are added at the end of three weeks and kept up until practically full-joint motion has been obtained. Success in this arthroplasty, as in all others, depends upon the surgeon's ingenuity in working out methods for starting early heat, massage, and exercise and in daily increasing the dosage and upon his persisting in the same until function is obtained (see Fig. 15).

FIG. 15.—*A*, crushing injury of the elbow with six fractures compounded and severely infected. Figure illustrates the final result following arthroplasty and prolonged physical therapy. *B*, same case as Fig. 15, a

PERIARTICULAR BONY OBSTRUCTIONS

Extension ankylosis is often due to bony deposits in the olecranon fossa of the humerus. Removal of the mass is necessary. When it is accompanied with irregular bony growths into the joint proper, arthroplasty may be necessary. Rotation of the forearm may be lost due to a fracture-dislocation of the head of the radius, and this must be removed surgically, as already indicated. Bony growth or synostosis may develop between the upper end of the ulna and radius

which must likewise be carefully dissected out and a fascial graft placed between the remaining fragments of the two bones to prevent recurrence. Physical therapy is indicated at once in all these cases.

PERIARTICULAR CONTRACTURES

There are cases which have such marked soft-tissue contractures about the joint that function cannot be restored by physical therapy methods alone. These are the cases in which we are so often tempted to do a *brisement forcé*. The usual form of deformity is stiff elbow in flexion position. When the biceps tendon and the brachialis anticus have become so contracted that they will not yield to physical therapy procedures, operative treatment is indicated. The incision is made over the anterolateral aspect of the elbow along the biceps tendon. The biceps and brachialis anticus muscles are exposed and the dissection is carried downward until the anterior aspect of the capsule and the tendons of these muscles are exposed. The biceps tendon is severed obliquely and the brachialis anticus is dissected from its attachment to the coracoid process. The capsule may have to be cut transversely before extension of the forearm is obtained. Following this operation a posterior splint may be applied or, better, a Thomas arm splint, with forearm traction. The latter allows early massage and the traction can be released twice daily for gentle active exercise which should start the day following the operation. The range of motion must be increased rapidly, but the extension must be maintained for three weeks or more to prevent recurrence of the contractures.

FLAIL ELBOW

Flail elbow, when it follows injury or an arthroplasty, must be protected by a hinged splint or converted into an ankylosis by an *arthrodesis operation*. Physical therapy is indicated here to maintain good muscle tone (Fig. 16).

POSITION OF FUNCTION.—When arthrodesis is performed or when ankylosis of the elbow is inevitable, an effort should be made to have the forearm in 45° of flexion and very slightly pronated.

HAND AND WRIST

While our interest in this chapter is chiefly related to trauma of the joints, yet it is impossible to consider these separately when it comes to the hand and wrist. So many injuries here involve more than one joint and in addition, nerves, tendons, fascia, and skin, that an article dealing with restoration of function must consider all these possibilities.

Loss of function in the hand can prove more disastrous to the majority of people than any other disabling joint condition. Every injury

in the wrist or hand should be viewed by the surgeon as a potential crippling condition. So many hidden injuries may be present and easily overlooked in the presence of a very apparent major injury that the greatest acumen is necessary to discover and repair each injury before irreparable damage has been done.

Loss of function in the hand and wrist may be due directly to the trauma or indirectly to mismanagement during the period of treatment. The latter can very easily be a matter of wrong judgment in planning the proper surgical treatment.

FIG. 16.—A, flail elbow following arthroplasty; B and C, flail elbow protected by a hinged leather brace

Causes of Loss of Function.—The commonest causes for loss of function in this region are:

(1) Severe swellings of the hand and wrist due to large hematomas and edema following, as a rule, severe crushing wounds or severe infection, usually fascial space infections

(2) Ischemia, due to the above swelling or to prolonged or too tight splintage or plaster cast and sometimes due to severe crushing injuries of the forearm or arm

(3) Fracture-dislocations, especially in the metacarpophalangeal joints or in the carpal bones, as a fracture or dislocation, or combination of both, in the semilunar bone

(4) Severed tendons, especially if accompanied with a joint injury

(5) Severed nerves, especially if accompanied with severed tendons and joint injury

(6) Extensive scar formation, such as the scars which follow electrical and other burns

(7) Colles' fractures, which very frequently result in deformity. (There is one type of Colles' fracture that invariably gives a deformity, but all other types should give full restoration of function after healing. Deformity will result if there is severe crushing and comminution of the lower end of the radius with much shortening. This shortening is difficult and at times impossible to overcome; it results in a change in the normal arc of the joint and is usually accompanied with marked cartilage injury. (Speed) The altered level of the radial styloid process invariably gives deformity and the injured cartilage frequently results in a certain amount of arthritis which is often proliferative.)

(8) Severed tendons high up in the forearm, which will cause a loss of function in the hand. (Likewise, excessive scar formation in the forearm may restrict tendon action with resulting deformity in the hand.)

(9) Severed nerves anywhere in the forearm, arm, or in the brachial plexus; nerves caught in callous or scar formation; and cord tumors.

Prevention of Loss of Function.—The multiplicity of injuries which may follow severe hand trauma requires common sense and good surgical judgment if all the contingencies are to be met. The question of prevention of loss of function must at all times be the first consideration.

Prevention of Tenosynovitis Contractures, Thickening of Aponeurosis.—It is impossible to keep the hand or fingers immobilized for any great length of time without a certain amount of fibrosis occurring in the soft tissues, especially in the tendon sheaths and about the joint capsules, resulting in a tenosynovitis, contractures of the capsule, and thickening of the aponeurosis, all of which may permanently restrict flexion or extension movements in the fingers or may require weeks and months of physical therapy treatment to overcome. Extensive, prolonged swellings of the hand can act in exactly the same way as mechanical prolonged immobilization; therefore, one must relieve this swollen condition as rapidly as possible. An ice-pack applied to

the swollen hand is sometimes sufficient, but if there has been hemorrhage under the fascia, this method is too slow. Large, hot fomentations are likewise often sufficient, but these hot fomentations must not be persisted in until the hand is water-logged and edematous. The elevation of the hand, alternating hot and cold packs, the whirlpool bath, hot soapsuds soaks, large packs of equal parts of alcohol and glycerin or saturated solution of magnesium sulphate, all may be tried and found useful. The surgeon should begin to worry about the persistent extensive swelling in the hand if it is not subsiding after 48 hr. It may become necessary to make multiple small incisions and evacuate the hematoma, although this is to be avoided if nt all possible, as infection is liable to follow the procedure. A solid swelling is more dangerous than an edematous swelling. The latter seldom needs incisions, while from the former large blood clots are often evacuated through incisions.

Prevention of Ischemia.— Ischemia should be feared by every surgeon who applies a cast to the forearm, wrist, or hand. If the hand and fingers become swollen, cyanotic, or blanched, or even are cold, and if this condition persists for a few hours, the cast should be cut either anteriorly or posteriorly and spread so as to relieve the pressure. No one should apply a cast or even double splints to the forearm and allow the case to go three or four days without the personal observation of the surgeon. It is far easier for ischemia and its subsequent contractions to develop than many physicians realize. Many ischemic contractions are never overcome, leaving the patient crippled for life.

Prevention of Contractures Following Infections.—Many prolonged and even permanent contractures of the fingers follow a hand infection which is treated by continuous hot fomentations over a period of ten days or two weeks. This is usually due to the fingers' being held in a faulty position within the large fomentations and to failure to instruct the patient to move the fingers frequently. Hot fomentations should not be continued too long. They should be changed several times a day and at each change the patient should be instructed to flex and extend his fingers, abduct and adduct his thumb, flex and extend the wrist joint, and otherwise prevent stiffness from developing. The supervision of these movements should not be left to the nurse who usually changes the hot fomentations. At each daily visit the surgeon should inspect the hand and make sure that the patient understands and is carrying out his instructions. I have seen large fomentations applied to the hand, and because of their weight, wristdrop develops. I have seen physical therapy administered for weeks to overcome this faulty position of the wrist. The importance of exercising the elbow and shoulder joint, and especially of keeping the arm at a right-angle abduction position during the period of use of large, hot fomentations, has already been mentioned.

Treatment.—EARLY MOVEMENTS.—Early and daily movements of the wrist, thumb, and finger joints are the prime essential in treating the majority of injuries of the hand. Seldom are casts indicated in a Colles' fracture or in carpal, metacarpal, or phalangeal fractures. If a cast is used, it should be changed to a splint within a very few days. Seldom should any splint be left on in this locality for longer than a week without removing it for massage and gentle active motion daily or, at the longest, every other day. Even in nerve injuries where rest is important, the cock-up splint or the posterior flexion splint, if the latter has been necessary in order to overcome the shortening in the ulnar or medial nerve defect, should be removed after a week for massage of the forearm, hand, and fingers, and very slight, but some, active motion of the joints, and very slight passive movement of those joints which have lost their power of movement. Casts and splints for injuries in the metacarpals, carpals, or forearm should never extend down over the fingers. These should be left free for movement and movement should be insisted upoo. Even in plastic operations where the hand and arm must often be encased in a cast to hold them in apposition to the nose or face, or when the hand has been buried under a pedicellate abdominal flap or in a skin flap on the buttock, the patient should be instructed in shrugging the muscles even though he cannot move the fingers.

ADEQUATE INCISIONS.—Faulty incisions for the drainage of hand infections account for many permanent disabilities. These incisions should never be made directly over a teodoo. Lateral incisions along the fingers will drain any tendon sheath infection. Through-and-through lateral drainage is not always indicated and should be avoided whenever possible. No surgeon should incise a hand without first familiarizing himself with all the fascial spaces, as clearly outlined by Kanavel. Small, inadequate openings and failure to discover deep-seated abscesses will often result in sloughing tendons and irreparable loss.

POSITION OF FUNCTION.—In many severe injuries of the hand a certain amount of loss of function is inevitable. Viewed from the standpoint of reconstructive surgery, such a hand should be placed from the outset in the position of greatest function. Fingers should not be allowed to stiffen in a completely extended position. Many a man has had an extended stiff finger amputated because it was in his way when trying to work with the remaining fingers. Attention to this principle of the functional position of the fingers will save months of tedious physical therapy made necessary by failure to correct a preventable condition. The position of function implies that the wrist is slightly hyperflexed. The palm is concave and the fingers are in the position of "grasping a tumbler" (Jones) or a ball. In this position the thumb is abducted and the ball of the thumb can usually be

brought into contact with the fingers. We are all familiar with the stiff fingers which are somewhat hyperextended in the two phalangeal joints. Flexion at the metacarpophalangeal joint may be present, but the hyperextended stiff fingers are responsible for the total disability. If they had been treated during convalescence in a position of semi-flexion, this flexion position at the metacarpophalangeal joints would then have meant 50 per cent or more of function.

Operative Procedures.—Operative procedures on the hand and fingers for the purpose of restoring function likewise require great surgical judgment. One must make sure that the joints are movable and can function before subjecting a patient to beautiful tendon operations. The tendon operation may be perfect, but if bony ankylosis or soft tissue contractures make it impossible for the joints to move, nothing will be gained. Thick, deforming scars may be dissected from the palm or the tendons may be freed from scars, and yet function may not be restored because of faulty condition of the joints. Again, one type of operation on the hand may require very early and very active movements if success is to follow, whereas another operation performed at the same time, for example, upon a nerve, may require rest; therefore it is foolish to perform both of these operations at the same time. The hand and fingers must be put in the best possible condition to make the proposed operative procedure a success. This usually implies several weeks of very active physical therapy treatment preceding the operation.

I recently operated upon a stiff phalangeal joint of the thumb. The stiffness was due to a partial dislocation with a small fractured fragment which interfered with joint movement. When I first saw it, I advised operation. The patient postponed operation for five months and then reported to the hospital to have it performed. Upon examining the thumb, I found marked atrophy of the muscles, both of the thumb and in the thenar space. Electrical tests showed innervation present. The condition was largely due to atrophy from disuse. The patient was from out of town and was accompanied by his wife. The two were sent to Dr. Coulter for physical therapy, preliminary to the operation. Three treatments were given and during these treatments the wife was carefully instructed relative to massage and redevelopment muscle exercises. They then returned home and the wife carried on this treatment. When they returned at the end of three weeks, we had a thumb worthy of operative effort. The operation was a success, due to the fact that the patient had sufficient muscle power and had been sufficiently trained so that he could carry on early active movements.

As a rule, old disabling conditions of the hand should receive heat by means of hot paraffin baths, whirlpool baths, very active hard massage, and passive and active exercises for several days preliminary to the proposed operation. Often one will see sufficient improvement

by these methods to justify postponing the operation, and several hands on which I have contemplated operations have recovered solely by these methods.

When an operation for restoration of function is contemplated on the hand or fingers, the strictest asepsis must be maintained and the least possible traumatizing of tissues must be done if the operation is to be successful. Infection will destroy tendon and nerve repairs and plastic operations upon the hand in the majority of cases. Every effort therefore must be made to avoid infection. The more bloodless the operative field, the less trauma will be done. The tourniquet therefore is essential. Many of these operations are long and tedious and an ischemia may develop from too prolonged use of the tourniquet. For this reason the inflated bag of a blood-pressure apparatus over the biceps is the best form of tourniquet to use. Occasionally the bag can be deflated, restoring circulation in the forearm and hand, and after a few moments it can again be inflated. Rough handling of the tissues, too severe retraction, especially by rake retractors, and dry sponging all predispose to adhesions with subsequent contractions and failure of operation.

COLLES' FRACTURE

Colles' fracture is the commonest injury involving the wrist joint. Every such fracture should be reduced early under either local or general anesthesia. The purpose of reduction is to secure the most perfect alignment of the fragments. Impaction may occur and may render reduction most difficult. Frequently there is serious derangement of the wrist-joint arc. The perfect correction of all these conditions can seldom be attained without an anesthetic. As soon as possible after reduction is made an x-ray film should be obtained, and if almost perfect realignment of the fragments and correction of the joint axis have not been obtained, an immediate second or third attempt should be made. If a general anesthetic has been given, the patient should not be allowed to awaken until one is sure that the reduction has been completed. This, of course, is one of the greatest advantages of local anesthesia.

In many Colles' fractures there is very little displacement and practically little manipulation is necessary. In these a simple posterior splint coming down to, but not including, the fingers is all that is necessary. After one is sure of his redaction in the more serious Colles' fractures, a posterior molded plaster splint again is usually all that is necessary. In fact, a Colles' fracture once perfectly reduced seldom flies out of position.

Movements of the fingers the first two or three days are usually painful, but the importance of movement must be stressed, and after one or two days, assisted active motion should always be started in the fingers.

In even the most serious Colles' fractures the posterior splint can be removed on the third day. The forearm should be carefully laid upon a flat, even surface, and heat in the form of hot packs and infrared light or an electric baker can be administered for a few moments, followed by careful gentle massage from the fingers up to the elbow. To be of the greatest benefit this massage should be rhythmical and always in the same direction. It should be in the line of the venous flow. In the absence of the apparatus for application of heat, alcohol, camphorated oil, or warm soapsuds may be used with the massage. After the splint is reapplied and before the bandage is put on, the forearm is turned over and its flexor surface is massaged, usually with alcohol. At the same time the fingers are exercised.

On the fourth or fifth day when the above treatment is administered, the patient is instructed to move his wrist joint to a slight degree. It is interesting how much movement some of these patients can stand. I have never seen the fragments of the fracture displaced by active movement. Forceful passive movement, of course, is definitely contraindicated. Every day, and at the least every other day, after this, the heat, massage, and exercise treatment should be administered and increased in dosage. Seldom is the splint necessary beyond two weeks. It can be replaced by a firm bandage or wristlet if the patient is fearful of having it free too soon. Often during the third week, I have the patient go without his splint during the day and apply it at night.

In a certain number of these Colles' fractures there are still swelling and limitation of motion at the end of three weeks. These cases are referred for more active physical therapy, consisting of prolonged baking, immersing of the hand and wrist in a hot paraffin bath, immersion in a whirlpool bath, followed by 30 min. of massage, and by assisted active and active exercises. Certain apparatus may be used to develop exercise, for example, the turning of a crank attached to a small wheel, the carrying of weights, the twirling of Indian clubs, and occupational therapy, for example, the use of a hammer several times a day. The more active movements here described can be started as a rule after the fourth week and should be persisted in until full function is restored. Loss of function in too many Colles' fractures is traceable to loss of interest on the part of the surgeon after the splints are removed.

In old malunited Colles' fractures (and the earlier the malunion is diagnosed, the better the prospect of functional restoration) refracture and realignment of the fragments approximating normal anatomic conditions is definitely indicated. As a rule, these malunions can be broken up by the use of a Thomas wrench. The procedure requires general anesthesia. Often a week of very thorough preliminary physical therapy is indicated before attempting refracture and realignment

of fragments. Following the procedure, physical therapy should be administered as described above, the more active movements being delayed possibly a week or two longer than in the case of the recent fracture (Fig. 17).

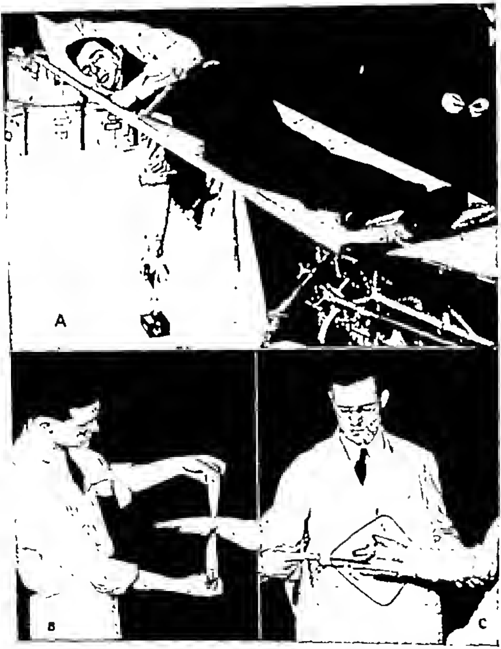

Fig. 17.—*A*, case of Colles' fracture being reduced by Dr. R. R. Duff's method of gravity and weight traction; *B*, method of applying traction strips in same case; *C*, method of applying banjo splint with traction strips attached to splint in same case.

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DISLOCATIONS OF THE INDIVIDUAL CARPAL BONES are not common. When dislocation occurs, it usually involves the semilunar bone. Immediate reduction, if possible, is indicated, but if complete reduction is impossible, it is far better to make an incision and remove this bone.

Failure to recognize this dislocation or attempts at reduction with incomplete success account for a certain number of cases of wrist-joint loss of function. When seen late, it is best to remove this semilunar bone, followed by traction and early active movement. Even before the wound is healed, massage and exercise as outlined under Colles' fracture, are indicated.

Whenever traction is used in any joint condition, especially the wrist joint, it should be frequently released to allow assisted active and active movement.

COMPLETE DISLOCATION OF THE WRIST is comparatively uncommon. Complete dislocation of this joint is always accompanied by extensive injury to the capsule, the ligaments, and possibly to the tendons.

When seen early, manipulation under anesthesia is usually successful. Old dislocations will require traction and the overcoming of contractures by heat and heavy massage for a number of days before attempting the reduction.

Following reduction, the same physical therapy maneuvers as outlined for Colles' fracture are indicated. Accompanying injuries, of course, must be repaired to insure function.

SPRAINS OF THE WRIST JOINT frequently follow falls on the extended hand, backfire of a motor when attempting to crank it, sudden jerks or twists when attempting to jump onto a moving street car, etc. A sprained wrist should always be x-rayed to rule out the possibility of fractures.

A true sprain of the wrist joint, often accompanied by sprains in the metacarpophalangeal thumb joint and by tenosynovitis, yield more readily to early active physical therapy treatment than they do to splints, casts, and disuse.

The early use of diathermy, followed by immersion in a hot whirlpool bath, and by massage (gentle at first and increasing in force as the days go on) will usually result in the cure of a sprained wrist within two to three weeks. Between treatments the patients are often more comfortable if a wristband or tight strapping is used.

STRAINS OF THE WRIST JOINT AND TENOSYNOVITIS of either the flexor or extensor tendons in the lower forearm are not at all uncommon. These are usually occupational conditions. I have seen a clerk taken from his usual work and sent to the packing room during the holiday season develop this condition after two or three days of using the hammer.

RADIOCARPAL AND CARPAL INJURIES

Severe crushing injuries of the wrist and *penetrating injuries*, such as gunshot wounds, are frequently followed by infection. Adequate drainage of the infection is necessary. Frequently there are open wounds on the flexor surface with or without involvement of the flexor tendons. It is far better to let these wounds heal than to attempt to drain the infected wrist joint through these accidental openings. A dorsal lateral incision, usually on the ulnar side, is the best approach for drainage of the wrist joint. It may be necessary to make bilateral incisions but more to the dorsal side.

The prevention of disabling deformities by placing such a wrist joint in the position of function—i.e., 30° to 35° dorsiflexed—is imperative in such injuries. This may be accomplished by a cock-up splint.

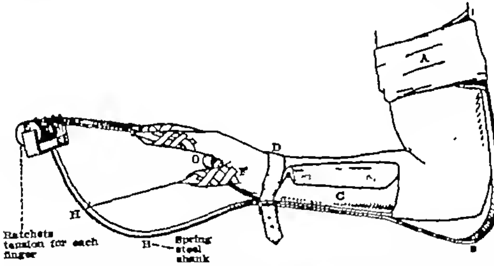

FIG. 18.—Method of traction used by Sir Robert Jones in injuries of the wrist joint. The method is also applicable for traction of stiff fingers. (From Sir Robert Jones' "Orthopedic Surgery of Injuries.")

Traction, keeping the carpal bones separated as much as possible, and especially separation of the radiocarpal joints, is extremely important in the presence of a wrist-joint infection. This can be accomplished by a banjo splint applied to the forearm with a strong wire loop extending downward six to eight inches below the fingers. Adhesive webbing can be attached from the web to the tips of the fingers and thumb with a rubber band extending from the adhesive webbing down to the steel wire loop of the banjo splint (Fig. 18).

Many of these cases are bedridden and can well be treated with a Thomas arm splint, the traction being applied from the fingers to the end of the splint. The chief point to remember is that function can later be more readily restored in the damaged wrist joint if traction and dorsiflexion have been maintained.

to 10 days the traction should be released for assisted active and active movements. Heat, massage, and exercise interspersed with continuous traction for at least a month will give fairly good function to the wrist joint.

Loss of rotation due to strong fibrous or bony ankylosis between the radio-ulnar joint is extremely disabling. The position of function for the forearm when rotation is threatened or inevitable is sligbt pronation, that is, about 25° of pronation from the medial position. When this condition is threatened, an arm should never be treated in complete supination or complete pronation. It is best to keep them in the above position from the outset.

Jones has described an operation for the relief of this condition. He advocates the removal of approximately a quarter of an inch of the ulna just above its bead. He reports good results in the restoration of rotation. Massage and exercise, started early, are necessary following this operation.

METACARPAL AND PHALANGEAL JOINTS

Dislocations of the carpal metacarpal joints are not common except in the thumb. They are usually easily reduced but may be difficult to bold in reduction. Firm felt padding over the point of dislocation with splintage is necessary.

In the case of a dislocation of a thumb, traction and abduction with pressure directly over the dislocation are usually sufficient. It may be necessary to maintain traction with the thumb extended. If possible, this should be avoided, but when necessary, the thumb should be released after one week for intervals of massage, flexion, and adduction exercises. These exercises and massage are likewise imperative in the fingers when the dislocation involves these. As a rule two weeks are sufficiently long for immobilization, followed by one to two weeks of very careful active motion before full use of the hand is resumed.

Dislocations of the metacarpophalangeal joints and phalangeal joints are fairly common. The distal bone is usually displaced posteriorly. These dislocations may be only partial, may be subluxated, and may then fly back into position so that, upon examination, no dislocation is found. Nevertheless the damage to the capsule with the accompanying synarthrosis is very disabling and may result in a permanent deformity, as is so often seen in baseball fingers.

These dislocations must be reduced by manipulation, consisting usually of marked byperextension of the distal bone which should be gradually pushed over the proximal joint surface until it drops into position. Open operation is often necessary but is usually neglected until the stiffened joint sends the patient for reconstructive surgery. Following the reduction of any of these dislocations, a simple, dorsal

Rest is imperative to relieve the condition, especially the sense of crepitus and pain observed in the tenosynovitis. A light splint is often necessary to obtain rest. It should be removed once or twice a day for heat, very gentle massage, and gentle exercise. The patient should be warned not to move the wrist joint beyond the point of pain. With the subsidence of pain, active exercise can increase. As a rule these conditions are quite pronounced before the patient seeks advice, and from two to three weeks are required to accomplish the cure.

Fractures of the carpal bones may result in stiffened wrist with difficulty in flexing the fingers. This is usually due to failure to prevent the wrist flexion which is prone to follow these fractures. Traction and dorsiflexion are likewise indicated in carpal fractures.

In old cases with stiffened wrist joint, weakness in the hand and loss of complete flexion power usually demand strong manipulative surgery. This is one of the conditions in which manipulation under anesthesia is justifiable. The purpose should be to produce strong traction and gradual correction of the partially flexed wrist, bringing it up into a position of hyperdorsiflexion. This should be followed by the cock-up splint which is removed daily for heat, massage, and exercise. After approximately one week the splint can be removed for longer periods and the hand and wrist immersed in a hot paraffin bath, a whirlpool bath, or a hot soapsuds local arm bath, followed by heavier massage and more marked exercise. It usually requires from four to six weeks to overcome this deformity.

Stiff wrist, the result of fibrous adhesions, may be overcome by strong manipulation under anesthesia if this is followed immediately by heat and light massage to prevent too great a reaction. Personally, I prefer to treat stiff wrist joints which are not due to bony ankylosis by strong traction, heat, and massage, or by the gradual manipulation of the wrist joint, pushing it toward the dorsiflexed position after a period of prolonged heat and massage. A cock-up splint should always be applied to maintain the dorsiflexion, and the cock-up position should be changed from day to day in order to maintain the improved position. The slower method is surer than *brisement forcé* under anesthesia, as it does not run the risk of tearing the ligaments and the contracted capsule with the subsequent marked reaction.

Arthroplasty of the Wrist Joint.—When bony ankylosis seems inevitable, every effort should be made to have the wrist joint stiffened in the functional position, viz., slightly dorsiflexed. If this has been accomplished, arthroplasty is seldom indicated following severe injuries. If free rotation of the forearm is present, the stiff wrist joint in hyperextension is preferable to a wrist arthroplasty.

When an arthroplasty is performed, traction should always be used to maintain the necessary separation in the new joint. After a week

one week in order to prevent a stiff joint. Finger traction from the outset is one of the best methods of treating this condition. Considerable movement can be maintained while the skeletal traction is in use.

FRACTURES OF THE METACARPALS *tend to bow forward, thus shortening* the metacarpal and destroying the normal arc of the metacarpophalangeal joint. The knuckle is lost and the head of the metacarpal can be felt in the palm. This deformity frequently results in a stiff metacarpal joint and often involves the function of the adjacent fingers. For this reason it is imperative to get good alignment in these metacarpal fractures.

FIG. 10.—Severe crushing injury of the hand with fractures of the third and fourth metacarpals of proximal phalanges.

BENNETT'S FRACTURE consists of a fracture at the base of the first metacarpal and extends into the joint. This fracture frequently appears after a fist fight. Traction with the thumb in the fully abducted position is the best method of overcoming this deformity and of protecting the joint function.

Physical therapy methods, as outlined for dislocations, must be followed in all these fractures and fracture-dislocations.

STIFF METACARPOPHALANGEAL AND PHALANGEAL JOINTS *are usually* multiple and are due to marked fibrosis, contracted capsule, and synarthrosis; these conditions following serious multiple injuries of the hand, often accompanied with fractures, or following prolonged disuse and fixation, or following ischemia, make up a fairly large part of reconstructive surgery. The surgeon's ingenuity is taxed to the limit

gutter splint or one made from plaster is sufficient. After a week it should be removed for heat, massage, and exercise. For at least three weeks only flexion exercises should be attempted, as redislocation by active extension is fairly easy.

Old stiff finger joints following dislocations, either nonreduced or only partially reduced, usually require operative procedure. The joint should be approached by a lateral incision and the capsule of the joint exposed and incised vertically. It may be necessary to incise on both sides of the joint and include the ligaments. Strong traction, hyperextension, and direct pressure over the joint are then used to reduce the dislocation.

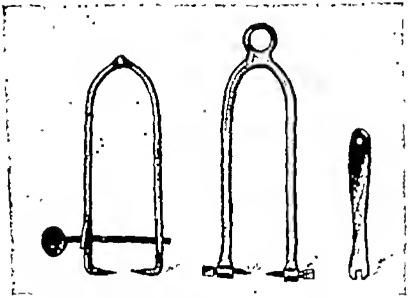

Fig. 19.—Author's finger caliper for skeletal traction.

Following this operation, I usually apply the Ellis-Mock finger calipers (Fig. 19) to the distal phalanx or the phalanx just below the dislocation and institute strong skeletal traction by attaching the calipers to the hoop of a banjo splint. The vertical incisions in the capsule are pulled into a somewhat longitudinal incision by strong traction, thus giving increased capacity to the joint capsule after healing.

After the third to the seventh day traction is released temporarily to allow slight active exercise. The amount of exercise is increased each day thereafter. The traction is maintained from two to three weeks. Heat, the hot paraffin bath, massage, and exercise are continued until full function is restored.

Fractures into the joints must be reduced and immobilized, but one should strive to start active movement early, often at the end of

to prevent this condition in the presence of such severe crushing injuries as are shown in Figure 20. The fractures in this case were treated by skeletal traction, leaving the soft tissues exposed for treatment (Figs. 21a, 21b). As a rule in the resulting deformity the hand is slightly cyanotic, a clammy sweat is present, the skin may be stretched and shiny, and there is definite atrophy in the thenar and interosseous spaces. The fingers are stiff or bend only slightly and are usually extended or only slightly flexed. In other cases due to old nerve injuries there may be marked contractions, giving the clawhand. Rarely is the hand stiffened in the position of function, that is, in the position to grasp a tumbler. Such a hand is frequently accompanied with a partially stiffened, partially flexed wrist joint. The thumb is usually pulled in toward the palm in adduction deformity.

Viewing such a hand, one feels that the impairment to its blood supply from the various causes of ischemia, from prolonged swelling immediately following the injury, or from the atrophy which follows disuse of the member is largely responsible for the congealed condition of the hand and the fibrosis which accompanies it. No condition calls for greater effort on the part of the surgeon and the physical therapy expert. Seldom has the surgeon the time and patience to render the necessary physical therapy to restore even partial function to such a hand. He must depend upon the specialist and his trained technicians who are thoroughly familiar with the various methods and modalities necessary to restore function.

Forceful flexing or bending of such stiffened fingers when first seen will serve only to cause great pain and frighten the patient. He becomes like a colt that is roughly bridled for the first time. If a physician has made his patient afraid to let him touch or even slightly manipulate the hand, the battle has already been lost because the necessary coöperation of the patient will not be restored or obtained. Gentleness therefore is the first essential. The second essential is never to bend stiffened fingers beyond the pain point. The third essential is to warn the patient and everyone connected with the case that it may take weeks or months to secure even a partial result. Finally, the fourth essential point is for every physician to know that forceful manipulation of such fingers under anesthesia practically always results in a marked traumatic reaction with a definite increase in the disability.

Seldom will the condition of stiff hand, as described above, develop in a patient who has been treated from the onset of his injury by the combination of surgery and the necessary physical therapy measures for preventing such a condition. If, however, in spite of all efforts or because of some unforeseen accident, a case has developed into this typical stiff hand, the treatment should be continued from the viewpoint of restoration of function. Do not let the patient become discouraged or lose confidence. Do not lose interest in the case yourself. It will require long painstaking effort, close attention

FIG. 21A.—Same as Fig. 20 with author's finger callipers attached for skeletal traction, leaving crushed soft tissues exposed for treatment.

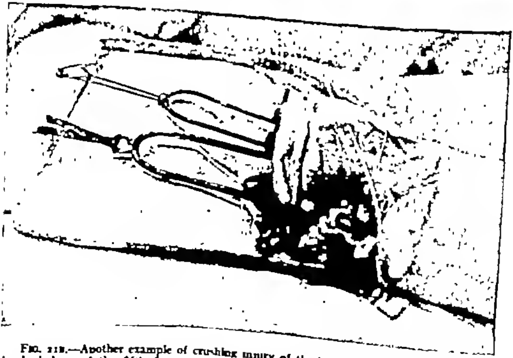

FIG. 21B.—Another example of crushing injury of the hand with fracture in the proximal phalanx of the fifth finger, treated by skeletal traction with author's calliper attached to a banjo splint.

inside boiler is filled with paraffin, such as is used in preserving. These cakes of paraffin can be purchased at any grocery store. The cakes of paraffin are now melted by hot water in the outer boiler—all except a small piece. If a piece is still unmelted, the paraffin is not too hot; if all is melted it may get too hot, and a thermometer becomes necessary. The hand is placed in the wax for one minute,

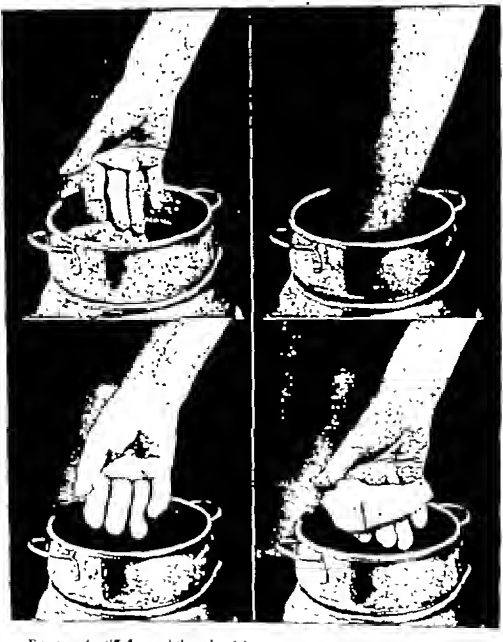

FIG. 23.—*A*, stiff fingers being placed in a paraffin bath; *B*, fingers and hand immersed in paraffin bath; *C*, hand removed from the bath and coated with hot paraffin; *D*, this hot paraffin glove, after it hardens, is easily stripped from the hand and fingers.

to the smallest details, constant supervision of the physical therapy technician, and the maintenance of this program for weeks and months to restore function, but complete or almost complete function is possible if one sticks at the job. Most of the cases of this nature will drift to a surgeon after the condition of stiff hand has developed. They usually come for operative treatment. Many things must be done before operation is considered if, indeed, it is eventually necessary.

Methods of Treatment.—Improvement of the circulation is one of the first considerations. Jones very aptly refers to this as "circulatory gymnastics." All methods which cause a vasodilatation in this extremity will improve the circulation. Many of these methods will, at the same time, soften the skin and the contracted aponeurosis and help redevelop the atrophied muscles; the combined methods will have a cumulative effect upon the ultimate desired result. In considering the various measures independently I want the reader to visualize the sequence of action and the adoption of several of the methods at each séance of treatment, instead of thinking of them as separate measures, any one of which may suffice:

CONTRAST BATHS.—Contrast baths consist of soaking the hand in hot water, hot soapsuds, or hot camphorated oil for 12 min., then immediately immersing the hand in cold water for 3 min. This should be repeated three times at one sitting. The sudden contrasts in temperature give a marked vasodilatation and are very efficacious for improving the circulation. They should be repeated daily. The temperature of the hot bath should be approximately 106° F. (41.1° C.) and can be increased gradually to 112° or 118° F. (44.4° to 47.7° C.). The temperature of the cold bath should be approximately 40° F. (4.4° C.).

ELASTIC BANDS.—Bier's method of promoting hyperemia in the extremity by the use of elastic bands around the forearm or by cupping or by more recent methods of motor-driven suction apparatus, all are beneficial in increasing circulation.

HOT PARAFFIN BATH.—The hot paraffin bath improves the circulation; softens the skin, fascia, and soft tissues; prepares the hand and fingers for massage; and is one of the most helpful measures that can be adopted. The patient can be instructed in making a paraffin bath to use at his home and he can use this method two or three times between treatments provided it is not contraindicated by some traction apparatus (Fig. 22).

The paraffin bath for the hands can easily be prepared at home by using a double boiler ordinarily used for cereals. This should be large enough for the hand to be placed in it up to the wrist. The

would fit the patient's deformed hand. A ball of dental wax is softened in hot water and then put around the handle, say, of a hammer. It is then dipped in cold water and immediately hardens, becoming a definite part of the handle. The handle is then dipped in hot water until the wax is softened again and the patient grasps the ball of wax as far as his restricted flexion movements will permit. An impression is made in the wax of each finger and thumb. The handle is then submerged in cold water until the wax hardens. The patient now has a tool with a handle that exactly fits his deformed hand. He uses this in the workshop and carries it back to the ward or to his home and uses it several times a day as a means of exercise. As the fingers flex further and the grasp improves, the wax can again be softened and a new impression of his grasp made. Since the War I have used this with great success on a number of patients.

Combination of Different Forms of Treatment.—Many combinations of the above maneuvers, giving heat and exercise at the same time, and massage and hydrotherapy simultaneously, and even occupational therapy and hydrotherapy, are utilized thus:

(a) A favorite therapy exercise of mine is to have the patient make 12 pulp balls and give them to me on my visit the next day. He is given a bucket of warm water into which he places a sheet of newspaper. He then immerses the stiff hand in the bucket of water and proceeds to work the sheet of newspaper into a pulp ball. The number of pulp balls he is to make is increased two a day. This is a very homely method but extremely efficacious (Fig. 23).

(b) The whirlpool bath has been mentioned many times in the text and has already been described. It is of great value in treating these stiff hands. While the hand is submerged in the whirlpool bath, or even a local bath, massage can be administered to great advantage.

(c) Women patients have reported that washing dishes or washing clothes in hot water has been of great assistance in overcoming their deformity. Men patients should not consider it effeminate to try similar methods.

Traction.—Traction is mentioned last but in a great many cases it is applied first and proves of the greatest value in overcoming the stiffened finger joints. In some cases continuous traction is indicated while in others traction apparatus is put on at night and works while the patient sleeps. So many different forms of traction apparatus have been described that no effort will be made to enumerate them here. The glove traction was developed during the War. Captain Abbott, at the Edinburgh War Hospital, is given credit by Jones for first using this method. He fitted a glove to the hand and attached elastic bands to the finger tips of the gloves and then attached the opposite end of the rubber bands to a dorsal plaster splint extending well beyond the

taken out for two minutes, and placed in for another minute. Keep this up for 10 min. Then allow wax to harden and remove as a glove. The temperature of the paraffin bath is approximately 110° F. (43.33° C.).

Massage.—Massage should be very gentle at first and then gradually increased, but never to the pain point. It should consist of stroking at first and later stroking and kneading, usually from the tips of the fingers upward through the palm, wrist, and forearm, following the line of venous flow. It should be persisted in for 30 to 45 min. Each séance is of importance and increases in importance as the case progresses toward recovery.

Muscle and Joint Reëducation.—Muscle and joint reëducation should be interspersed at frequent intervals during the 45 min. of massage. This variation prevents both the patient and the technician from becoming fatigued. Many of these patients have forgotton how to close the fingers and must be reëducated. Flexing the same joint on the opposite hand while attempting to flex the injured joint is an excellent means of reëstablishing joint habit. At first, muscle-training exercises consist of having the patient concentrate upon the effort of flexion or extension, even though he has no power of performing the movement, at the same time the technician flexes or extends the finger as far as possible without causing pain. This is tedious work, especially when every joint in the hand must be treated in this manner. The surgeon or, if the case has been referred to a specialist in physical therapy, the latter should frequently supervise the treatment to make sure that none of these steps are being neglected.

Exercise.—Exercise, especially voluntary exercise by the patient himself, is of the greatest importance. We can perform all the other measures, but unless the patient will coöperate to the fullest extent in developing voluntary exercises, function will never be restored. At first exercises may have to be passive; later, assisted active exercises may be added; and finally, exercises may be performed by the patient himself. Resistant movements are the best, that is, flexion or extension while the technician is resisting the movement. Many mechanical devices have been made to stimulate exercise in the fingers. Those which require voluntary effort on the part of the patient are the most successful.

Occupational Therapy.—Occupational therapy, which furnishes one of the best forms of stimulating exercise, should be instituted as early as possible. Dr. Allen, of Indianapolis, early in our participation in the World War first suggested the use of dental wax applied to a hammer, saw, and plane or similar tools to make a grasp which

a woven-like manner around each finger from the web to the tip, and to the ends of the adhesive straps are attached strong rubber bands. The opposite ends of these bands are attached to the loop of the banjo splint (see Fig. 18). As the flexion of the fingers improves, the wire loop can be bent into a position of greater and greater flexion. The bands should be tightened as the patient develops greater

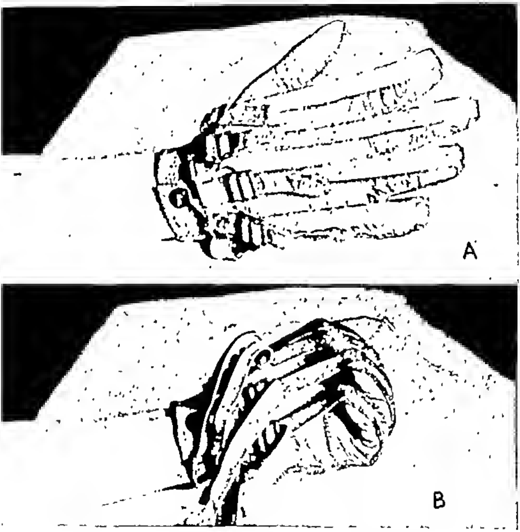

Fig. 14.—*A*, method of glove traction used by author; *B*, same as Fig. 14, a.

tolerance. The traction must be freed several times a day for active exercises by the patient, especially exercises aimed at extension and then flexion to the point thus far gained. Traction is always necessary where there are marked contraction and stiffness in the phalangeal joints. Failure to use traction in these cases jeopardizes the result. Only slightly forcing flexion, or conversely, extension, in these joints

fingers. The rubber bands gave a constant pull extensionward. Many variations of this principle have been made, notably, straps sewed to the tips of the glove fingers and extending backward through rings or leather loops to a wristlet attached to the glove and containing buckles. The patient is instructed to tighten these leather bands in the buckles until he has as much extension traction on the flexed fingers as he can stand. Both of these procedures are reversed when the

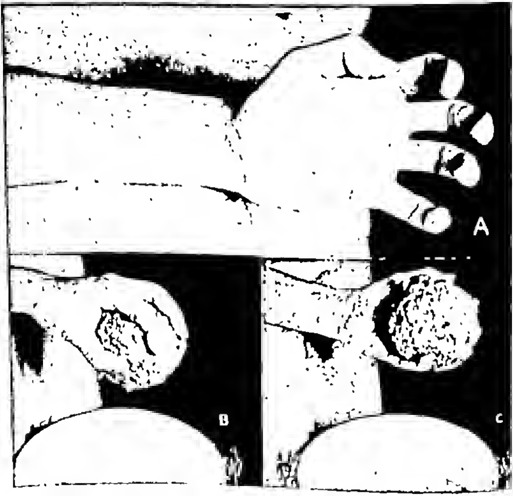

FIG. 23.—A, deformed hand following severe infection; B, same patient making pulp balls from newspaper; C, same as Fig. 23, b.

fingers are in extension and flexion traction is desired, which is the usual condition in the stiff hand (Fig. 24).

The banjo splint—that is, a loop of strong wire attached in a plaster cast around the wrist and lower forearm, each leg of the loop running down alongside of the hand and the loop itself protruding beyond the fingers some six inches—forms the base for most finger traction used today. Two strips of adhesive are then interlaced in

of these conditions. In all these cases the principles of physical therapy, including traction and splintage, are definitely indicated in the treatment.

Hip Joint

Associated Disturbances.—Loss of function following injuries to the hip joint are often associated with functional disturbances in the knee and ankle joint.

In fractures of the femur, disuse from prolonged immobilization often results in fibrosis, both in the hip and knee joints.

Traumatic arthritis is not at all uncommon in the hip joint, especially in older individuals. It may follow a direct blow over the hip joint or force applied indirectly to the hip joint, as when a patient falls a distance and alights upon his feet. Frequently the first x-rays of the hip joint will show some osteo-arthritic changes present in the uninjured, as well as in the injured, joint and also present about the sacro-iliac joints. A later x-ray, say three months later, may show a definite increase in the osteo-arthritis of the injured hip joint with no change observed in the later film of the uninjured hip. This is definite proof of an aggravation of an old osteo-arthritis of the hip which was latent and is a very common phenomenon. In older individuals it is always wise to x-ray both hips for comparison.

Fibrosis may follow a suppurative arthritis of the hip joint. As a rule, however, the acetabulum, the head of the femur, and occasionally the neck of the femur are involved in a suppurative arthritis, developing an osteomyelitis and marked destruction in and about the hip joint, which requires operative treatment. Another not infrequent cause of hip joint loss of function in the presence of a suppurative arthritis is the spontaneous dislocation of the hip joint which usually occurs in the presence of a long-continued suppurative process in this joint.

Bony ankylosis usually follows trauma of the hip joint whenever a suppurative or tuberculous infection supervenes.

Prevention of Loss of Function.—Traction treatment of fractured femurs, especially skeletal traction, permits of early mobilization of the hip joint and does away with many of the cases of fibrosis.

In intracapsular fractures of the neck of the femur Whitman's abduction method with the body cast may be used for a great many weeks without loss of function in the hip joint. However, in many cases prolonged physical therapy methods must be used to restore function. Recently Jones, of California, has developed a traction apparatus (Fig. 25) which can be applied with the fixed arm of this instrument in a plaster cast on the lower normal leg and with the movable arm attached in a plaster cast on the lower leg of the injured side. By means of the screw shaft, traction can be applied to the injured leg with countertraction in the fixed arm of the instrument attached to the well leg. I have used this in three cases in which the

may so erode the joint surfaces that a traumatic arthritis is developed by the treatment.

In a few obstinate cases I have used Mock's finger calipers attached to the distal phalanx, combined with a banjo splint to obtain necessary traction. Likewise I have used finger-nail traction. A hole is bored through the distal edge of the nail and a soft wire or silk thread is drawn through the hole. The rubber band is attached to this and then to the loop of a banjo splint. In case of traction on one finger only a single splint protruding six inches beyond the finger can replace the banjo splint (see Fig. 20).

Splintage.—Splintage must be used whenever indicated. The cock-up splint to maintain the wrist at a 25° to 30° dorsiflexion is frequently indicated. It will be noticed that improvement in the flexion of the fingers follows placing the wrist in this position.

Operation.—In a few obstinate cases of ankylosis of the finger joints, due to contraction of the capsule and adhesions, I have had some excellent results by the following simple operation:

A small blade, sharp knife is inserted through the skin on either lateral aspect of the affected joint and a vertical incision is made through the joint capsule. As attempted flexion of the finger is made, one can usually feel the tense bands of adhesions or foreshortened ligaments with the knife blade, and these are incised. The finger is then flexed gently and gradually until full flexion is obtained. Next Mock's finger calipers are applied through the skin and into the bony phalanx just distal to this joint. The ring of the calipers is fastened to the loop of a banjo splint by a rubber band to maintain traction which separates the articular surface and tends to pull the vertical incision in the capsule into an elongated or longitudinal line. Early passive and, after a few days, active motion can be utilized in the affected finger even while the traction is maintained. This method is especially applicable to an obstinate stiff joint in a single finger.

Flexor contractions usually follow nerve injuries. The stiffened joints which develop in these contractures should be treated as just outlined above, except that the method of traction must be reversed.

MISCELLANEOUS CONDITIONS

One or more of the joints of the wrist, hand, and finger are often involved in nerve injuries, causing the so-called clawhand, in von Volkmann's ischemic paralysis, occasionally in Dupuytren's contracture of the fascia of the palm, and following distant injuries, especially elbow-joint injuries and in the lower third of the humerus which involve the musculospiral nerve and in injuries to the brachial plexus.

There are certain operative procedures that are indicated in some

entirely over the lower abdomen and pelvis. Following the application of heat, firm stroking and kneading massage should be instituted. At first the surgeon should daily assist the patient in a certain amount of active exercise, and as soon as it is safe, the patient must be encouraged to continue and increase active exercise. The amount and dosage of these methods must be increased daily.

SUPPURATIVE CONDITIONS

In suppurative conditions of the hip joint the patient usually becomes cachectic and anemic. While the above local administration of physical therapy will help restore function to a certain extent in the hip joint, general physical therapy in the nature of quartz-light violet rays, combined with cod liver oil, is extremely important and should never be neglected. If the patient can be moved outdoors in the sunshine, heliotherapy is definitely indicated.

DEFORMITIES RESULTING FROM FIBROUS FIXATION

Deformities which are the result of fibrous fixation require traction, occasionally splintage and heat, massage, and active exercise. The usual deformity is flexion of the hip joint and increased lordosis of the lumbar spine. Often the flexion deformity is accompanied with marked contraction of the adductor muscles near their origin.

In younger people subcutaneous incision of the contracted adductor muscles, followed by manipulation of the hip joint under anesthesia, and followed immediately by prolonged heat, massage, and assisted active and active exercises, will often result in restoration of function. If the condition is the result of septic processes, it is questionable whether this procedure should be followed. Certainly several months should elapse before it is attempted. During the waiting period prevention of further deformity is indicated.

In older individuals it is much wiser to resort to slow traction on the lower leg to overcome the flexion deformity, accompanied with daily physical therapy treatments, as already outlined. Even in old people it may be necessary to sever the adductor muscles subcutaneously near their origin before their flexion deformity can be overcome.

The opposite or normal hip should be exercised daily by flexing the thigh completely on the abdomen in order to help overcome the lordosis deformity. In the case of old fractures or in old people, no undue force must be used in this manipulative procedure, even of the well hip, because of danger of refracture or of fracturing the neck of the femur in the uninjured hip.

ANKYLOSIS AND OLD DISLOCATIONS

Bony ankylosis of the hip joint and old hip dislocations frequently require operative procedure. In the young person, arthroplasty of the

deformity in the neck of the femur was definitely overcome. By the use of this apparatus early mobilization of the hip joint can start.

When suppurative processes develop in the hip joint following injury, they must be opened and drained. A drainage tube placed in the hip joint causes erosion of the joint cartilage and invariably leads to ankylosis. Therefore, if drainage is necessary, a tube or Penrose drain can be sutured to the cut capsule above and below, thus forming a tunnel. A slight pull upon these drains will keep the capsule wound wide open. Traction on the lower leg is essential to overcome the abduction position of the thigh and the flexed position of the knee which practically always accompany this condition. The traction

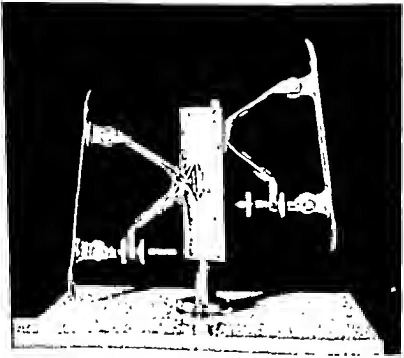

FIG. 15.—The Carl P. Jones traction reduction splint for fractures about the neck of the femur and dislocations of the hip.

apparatus should be released several times a day and active movement of the hip joint by the patient should be insisted upon.

Early function in the hip joint by the use of walking calipers has been an excellent means of preventing loss of function in this joint following injuries in the lower extremity.

Restoration of Function.—If prolonged immobilization by the body cast has been necessary, just as soon as the cast is removed physical therapy should start. These patients are usually still bedridden. Heat can be applied to the hip joint in the form of large fomentations, an infra-red lamp, or a large electric baker which fits

during the last 14 months I have had two cases of ununited fractures of the neck of the femur—one in a man of 26 and the other in a man of 40 years of age. I operated on both of these patients, performing a modified Bracket operation. Good union and 80 per cent function in one case and 60 per cent function in the other were obtained chiefly by the early and persistent use of physical therapy methods as already outlined.

Fig. 16b.—Same as Fig. 16a following two weeks of heavy skeletal traction. The head is pulled down almost to the level of the acetabulum. (The acetabulum is completely filled with a fibrocartilaginous growth.)

hip may be justified. In older individuals, this procedure is questionable. If the ankylosis is in a badly deformed position, transtrochanteric or subtrochanteric osteotomies may be considered (Figs. 26a, 26b, 26c).

UNUNITED FRACTURES OF NECK OF FEMUR

Ununited fractures of the neck of the femur in old individuals are not uncommon, but they are rare in young individuals. Nevertheless,

FIG. 26a.—Author's case of old dislocation of the hip, six months' standing, in a man 53 years of age

KNEE

Causes of Loss of Function.—Loss of function in the knee joint accounts for a large percentage of the handicapped people in civilian life. Lying as a pivotal point between the large thigh bone and the large bones of the lower extremity, it is practically always involved whenever a fracture occurs, either above or below the knee.

FRACTURES OF KNEE

Longitudinal fractures through the head of the tibia directly into the knee joint and fractures of either the lateral or medial condyles of the tibia, "T" fractures through the condyles of the femur, fractures of the head of the fibula, and the fractured patella are the most frequent direct types of fracture deranging the knee joint. Fractures of the patella may be accompanied by a direct injury to the synovia and capsule and the interior of the knee joint or may indirectly affect the function of this joint. Within the knee joint proper, fracture of the tibial spine is the commonest type of disabling fracture. Occasional sprain fractures with the tearing off of one or more of the attachments of the crucial ligaments occur. The usual example of this type of sprain fracture is the tearing away of a part of the articular surface of the tibia in the vicinity of the attachment of the anterior crucial ligament.

STRAINS OF KNEE

Strains of the knee are not at all uncommon. They differ from sprains only in the degree of force and length of time of action of force upon the knee joint. Strains of the knee may be followed by a synovitis, but it is never as persistent a type as is seen in sprains; neither does it tend to recur. Failure to relieve the synovitis in strained conditions may lead to a thickening of the synovia, hypertrophy of the villi of the synovia, and calcification. Heavy individuals often complain that their knees are weak. Repeated slight strains are not uncommon in such people. The slight, frequently recurring synovitis may gradually lead to thickening of the synovia and a form of traumatic synarthrosis. This may or may not be painful. Such individuals, especially heavy women, complain of cracking and grating noises in their knee joints, particularly when climbing stairs. This form of arthritis is more probably due to this repeated slight trauma than to toxic causes; otherwise, why does it seem limited to heavy individuals and especially to heavy women who have a weaker protective mechanism about the knee joint?

Functional Position.—When partial or complete ankylosis of the hip joint is threatened or inevitable, one should place the thigh in the position which will tend to give the best function. As already indicated, the commonest deformity of the hip is flexion and adduction. When ankylosis is inevitable, effort should be made to place the thigh in an extended, sligbtly abducted position, with slight outward rotation.

Fig. 16c.—Same case following open reduction of the old dislocation. (The fibro-cartilaginous exudate was completely reamed out of the acetabulum before this dislocation could be overcome.)

INJURIES TO SEMILUNAR CARTILAGES

Injuries to the semilunar cartilages can become extremely disabling and may account for many of the permanent disabilities within this joint. Displacement or fracture of the external semilunar cartilage is comparatively rare and does not give the marked symptoms usually found when the internal cartilage is involved. Locking of the knee seldom occurs. The commonest sign is a catch and then a sudden jerk or slipping just before complete extension of the knee is accomplished. This catch or slipping is referred by the patient to the external aspect of the knee, and the surgeon, with his hand over this area, can usually feel the condition. Certain phlegmatic individuals may ignore the condition altogether, but others, especially if compensation is involved, worry over such an injury, often making operative procedure compulsory.

Displacement or fracture of the internal semilunar cartilage is a disabling condition. It is usually accompanied by marked effusion into the joint, pain, and a locking of the joint. These symptoms may subside and may not recur for months or years. I seldom operate after the first attack if it shows signs of subsiding. Recurring attacks of synovitis, pain over the internal semilunar cartilage, or recurrence of locking makes operative procedure justifiable and often necessary.

JOINT MICE IN KNEE JOINT

Osteochondritis dissecans and joint mice are practically as common in the knee joint as in the elbow joint. They frequently follow trauma, or may be a late condition in the synarthrosis described above, or may follow a definite arthritis of this joint. Rice bodies tend to form in fringes of the torn synovia. Hypertrophy of the synovial villi followed by calcification is frequently the source of these joint mice. When present, they can simulate dislocations of the semilunar cartilages, and when trauma reveals the first manifestation of their presence, differential diagnosis from injured cartilage is difficult. An x-ray usually shows their presence, whereas an x-ray seldom shows a dislocated cartilage. It is important to make the differential diagnosis because, in the operative procedure, the knee joint must be more thoroughly exposed for removal of joint mice than is usually necessary for cartilage operation.

DISLOCATIONS OF KNEE

Dislocations of the knee are more frequent than formerly, due to the extreme violence of many present-day accidents, especially automobile accidents. There are three varieties, the dislocation being named according to the displacement of the tibia, as follows: (a) forward dislocation; (b) backward dislocation; (c) lateral dislocation.

These conditions, of course, are totally disabling unless they are fully reduced. The loss of function which follows a dislocation is due

SPRAINS OF KNEE

Sprains of the knee are second only to fractures as a cause of loss of function in the knee joint. Tearing of the internal lateral ligament is the commonest form of sprain. If it tears at a point on a level with or above the internal condyle of the femur, the internal semilunar cartilage is rarely involved, but a tear below this level is usually accompanied with a displacement or a fracture of the internal semilunar cartilage. Such a condition is accompanied by a marked synovitis, and, if the semilunar cartilage has been involved, there is usually a recurrence of the synovitis.

Sprain of the external lateral ligament is not a frequent occurrence. It is not usually accompanied by a synovitis, neither is the external semilunar cartilage damaged by this sprain.

Sprains of the crucial ligaments, usually a stretching or a complete rupture of one or both, may occur without any evidence of fracture. The anterior crucial ligament is more frequently damaged than the posterior. The anterior crucial ligament is attached to the internal prominence of the spine of the tibia and the external semilunar cartilage is attached to both the ligament and the spine of the tibia. Frequently in injuries of the anterior crucial ligament the spine of the tibia is torn off and displacement of the external semilunar cartilage occurs.

Stretching or rupture of the posterior crucial ligament alone is very rare. Cubbins, of Chicago, is of the opinion that this injury is commoner than is supposed and that it is frequently overlooked. Damage to this ligament usually occurs in severe dislocations of the knee joint.

In the presence of a persistent synovitis with pain on pressure over the region of one or both semilunar cartilages, a diagnosis of injury of the semilunars is frequently made. The increased anteroposterior and lateral movements of the knee joint are not evident because of the persistent effusion and swelling. In many cases the semilunars are operated upon and removed. The escape of the effusion at the time of the operation and the prolonged rest following the operation alleviate the swollen condition of this joint. When the patient is allowed up and movements start, the loose knee joint is discovered. Often the patient attributes the condition to the previous operative procedure, whereas it is due to the undiagnosed injury to the crucial ligaments, usually the anterior.

SPRAIN-FRACTURES OF KNEE

Sprain-fractures have already been referred to. In a sprain of the internal lateral ligament, a chip fracture at the point of its attachment to the femur is frequently revealed by the roentgenogram. Likewise, the x-ray may show a chip fracture from the head of the fibula in sprains of the external lateral ligament.

PENETRATING WOUNDS OF KNEE

Penetrating wounds of the knee joint are common. When a foreign body has penetrated the knee joint, it must be removed. If the penetrating body is a piece of steel or a bullet, removal can usually be done at once. If the material is dirty and infection is liable to follow, early removal must be followed by adequate drainage for possible infection. If infection has already developed, immediate drainage with later removal of the foreign body may be preferable.

External wounds of the knee joint, for example, severe lacerations and severe burns, may result in a complete loss of function due to scar-tissue formation.

DISTANT INJURIES WHICH AFFECT KNEE

Distant injuries may account for loss of function in this joint. It is not uncommon to see a stiff, flexed knee joint following an amputation in the upper third of the leg. Fractures in the extremity distant from the knee joint can easily result in a stiff knee due to contractures and fibrosis. Atrophy of the strong muscles and aponeurosis surrounding the knee joint due to prolonged immobilization of the extremity, prolonged disuse, cord injuries, or other causes for paralysis may frequently result in definite loss of function in this joint. Following fractures in the foot, a marked flatfoot condition may develop. Following a prolonged illness, after which the patient is allowed out of bed to walk around in carpet slippers while the muscles are still in a weakened condition, may result in a flatfoot. As one grows older he may develop a flatfoot. This condition of flatfoot frequently causes derangements of the knee joint which may become very disabling.

Prevention of Loss of Function.—In addition to the preventive measures already referred to in remarks concerning loss of function, certain general principles must be observed in all knee-joint injuries if loss of function is to be prevented in many of them.

Careful Diagnosis.—Diagnosing the injury as an *internal derangement of the knee joint,* allowing the patient to continue to use that joint when careful study and observation might reveal *the definite nature of the injury,* thereby allowing institution of proper early treatment, accounts for a great many cases of prolonged disability and occasionally a permanent loss of function.

Accurate Diagnosis of Each Injury.—Multiplicity of injuries which may follow severe knee-joint traumas require in this joint, as in the shoulder and elbow joints, accurate diagnosis of each injury and the adaptation of that line of treatment which will give the greatest protection to ultimate function.

to the tearing of the lateral ligaments and to the stretching or rupture of internal crucial ligaments. Injuries to the popliteal vessels or nerves must always be kept in mind. Pressure upon the popliteal artery if the dislocation is left reduced may cause gangrene. In one of my cases of dislocation of the knee there was immediate evidence of injury to the anterior tibial nerve, and within a few hours a cold, blanched lower extremity was noted. In spite of early reduction of the posterior dislocation, the lower extremity became gangrenous. An amputation was finally necessary. Immediately following the amputation Dr. Hirsch, pathologist at St. Luke's Hospital, dissected out the structures in the popliteal space. There was no evidence of external injury to the popliteal artery, yet the intima of this artery had been torn completely loose and washed downward for approximately two inches, at which point it completely blocked the lumen of the artery. A considerable thrombosis formed above this point of block.

TRAUMATIC ARTHRITIS OF KNEE

Traumatic arthritis has already been mentioned. It can easily be a late development in knee-joint trauma. Contusion of the joint cartilage cannot be recognized in early x-ray pictures, and yet films taken several months later may show definite evidence of bony proliferation, the picture of an osteo-arthritis. This condition may progress until the joint function is completely destroyed, when ankylosis will follow. This type of arthritis is usually due to a combination of the trauma plus invasion of the knee joint by infection. Frequently traumatic arthritis is a late development from injuries to the synovia. The synovial fringes may be contused by impinging between the joint surfaces or there may be tears and hemorrhage into the fat pads, especially the infrapatellar pads and the fat contained within the ligamentum mucosum. Contusion of a fat pad, followed by hemorrhage and swelling, followed by fibrous and frequently calcareous changes, may be the source of the arthritis and may eventually result in the formation of joint mice as described above.

The knee joint is not an infrequent site for purulent arthritis, especially in children and young adults. There is often a history of slight trauma, followed by an invasion of the joint from pyogenic organisms within the body, and by abscess formation. Due to the firm tissues surrounding this joint, too many cases of purulent arthritis go undiagnosed until the x-ray shows definite damage to the joint cartilage and surrounding bone. Loss of joint function frequently follows this condition. Early diagnosis, adequate drainage, *the avoidance of drainage tubes within the joint*, and early mobilization of the joint after drainage are the only means which will prevent almost complete loss of function in the knee joint following a purulent arthritis.

their feet or, if this is impossible, to use walking calipers. When calipers are impractical, the patient should use crutches. Weight-bearing, as already indicated, is an excellent preventive measure when mobilization of the joint is contraindicated.

Early Drainage.—Extensive swellings of the knee joint from effusion or hematoma should be relieved as rapidly as possible. Rest, heat, alternating heat and cold, and occasionally massage may be sufficient. However, in the more severe effusions, aspiration, and (if it recurs) repeated aspiration are far better than to allow the overstretching of the capsule over a period of weeks. When there is a hemoarthrosis, early aspiration will frequently prevent blood-clot formation with subsequent organization and fibrosis and often traumatic arthritis of the various types already described.

The early diagnosis of pus within the joint and early drainage before great damage is done to the joint cartilages or adjacent bones is absolutely essential if complete loss of function is to be avoided.

Traction.—Traction, thereby separating the joint surfaces, is equally as important in the knee joint in many conditions as in the joints already described. Whenever possible, this traction should be so arranged that it can be released for active knee-joint movement at least twice a day. In the majority of cases where traction is necessary for fractures in the femur, and adhesive traction bands are used across the knee joint, release of the traction for knee-joint movement is impossible. For this reason, skeletal traction through the condyles of the femur, leaving the knee joint free to be moved, is preferable.

Early Treatment.—The earlier heat, massage, and active exercises can start in an injured knee joint (depending upon the nature of the trauma), the surer are the possibilities of restoration of function.

Mobilization of Patella.—The importance of mobilizing the patella in practically all knee-joint injuries and in all knee joints where prolonged immobilization is necessary, or has been instituted, must be emphasized and reëmphasized. The tendency of the patella to become adherent to the infrapatellar tissues, the fibrosis of the bursae about the patella, and the contraction of the patellar ligament, is the commonest cause of stiff knee joint. Even when massage and exercise of the knee joint proper are impossible, that line of treatment should be adopted which leaves the patella exposed for massage and frequent lateral and up-and-down movements. Surgeons have learned the importance of keeping the foot elevated at a right angle to prevent foot-drop and the importance of placing the arm, in the case of wristdrop, in a cock-up splint; they are more and more learning the importance of treating the injured shoulder in the abducted elevated position; but the importance of the mobilization of the patella, which falls in the same preventive category, is not appreciated or is too frequently

Early Function.—Prior to the War the majority of us, unable to recognize many of these obscure injuries, were satisfied with the diagnosis of internal derangement or sprain of the knee joint and resorted to the time-honored treatment of immobilizing the knee in a plaster cast for a period of several weeks or months. Fortunately, in the younger people nature was kind and restored full function after such treatment. In older individuals, however, prolonged immobilization usually resulted in a stiff or partially stiff knee joint.

It is noteworthy that in the knee joint, synarthrosis, thickening of the capsule, contraction of the ligaments, and adhesions within the joint are not so common following prolonged immobilization as is the case in joints of the upper extremity. The exception to this is when the patient is bedridden and the knee is immobilized, especially in a cast. In this group, soft-tissue stiffness of the knee joint is common. Complete immobilization of the joints in the upper extremity is practically always associated with complete disuse, whereas complete immobilization of the knee in a splint or plaster cast, provided the patient is not bedridden, is always accompanied with a certain amount of use. Even though such a patient walks on crutches, the injured lower extremity is swinging, is being lifted to an elevated position when the patient sits down, and is otherwise moved. A patient who has his knee immobilized and yet is allowed to walk upon that extremity is receiving more movement and exercise in the knee joint than we usually suspect. Undoubtedly it is this limited exercise and limited continuation of function that prevents more severe damage in prolonged immobilization of the knee joint. We have in this example an excellent criterion for the functional treatment of all joints when immobilization of either the upper or lower extremity is necessary. Active movements of the upper extremity and movements and weight-bearing in the lower extremity are essential if loss of function in their various joints is to be prevented. Patients who have the knee joint encased in a plaster cast while the joint is still somewhat swollen frequently complain that the cast is loose after three or four weeks. If they only knew it, this is a direct gift from the gods, for it allows a certain amount of motion which is greatly to be desired.

Early Massage.—As far as possible, all injuries of the knee joint should be treated by early massage. This is especially true in fractures of the lower extremity which require the patient to be bedridden. A cast extending across the knee joint in a bedridden patient always results in a stiff knee, which is overcome only after weeks of prolonged effort. In older individuals it is frequently never overcome.

Walking.—There are severe injuries within the knee joint and severe injuries in the lower extremity that require prolonged immobilization, often with a cast. Loss of function in the knee joint can be prevented or greatly reduced by allowing such patients to walk upon

For the last five years it has been my custom *never to apply a posterior splint to the knee joint following this operation.* The case is usually operated upon in the morning. In the afternoon I visit the patient and show him the loose, padded bandage which has been applied to the knee joint and instruct him that he is to move the knee as far as possible within this bandage. The patient can be trusted not to move it beyond the pain point. Each day I instruct him to move the knee more and more, and by the time the stitches are removed on the ninth or tenth day the majority of these cases have from 25 to 50 per cent knee-joint movement.

FIG. 27.—*A*, case of fracture-dislocation of the internal semilunar cartilage two weeks following operation. *B*, same case as Fig. 27,a, showing the amount of knee function two weeks after operation. Active movements of the knee joint were started immediately after the operation, resulting in almost complete function at the end of two weeks.

neglected. In all cases of fractured patella which have been operated upon, daily, and better, twice daily, exercise of the patella is of prime importance. Most of us know this fact, but, let it be said to our shame, few of us take the time every day to insist upon it.

Treatment.—In intra-articular injuries there are certain ones which demand mobilization treatment and others which require prolonged immobilization.

SEMILUNAR CARTILAGE INJURIES

Synovitis

In semilunar cartilage injuries, correction of the locking, if present, is immediately necessary, followed by relief of the marked synovial effusion, usually by aspiration, and followed by a period of rest of the joint for two or three weeks. When seen early after the injury, these cases should be hospitalized and rest should be obtained by keeping the patient in bed. Large, hot fomentations applied to the knee with or without aspiration of the effusion furnish sufficient immobilization. After three or four days the patient should be allowed very slight active movements while in bed. If there is a tendency for the effusion to recur, necessitating reäspiration, the period of rest in bed may be prolonged, or, after two weeks, the patient may be allowed to walk on the extremity provided the knee joint is strapped or bandaged tightly. The walking and the limited motion allowed within the strapping are sufficient exercise to prevent fibrosis.

In cases seen late with effusion still present, aspiration of the effusion, followed by tight strapping or bandaging and allowing the patient to walk, is usually sufficient. In the latter case aspiration is frequently done in the office. The same meticulous asepsis relative to sterilizing the needle and preparing the field for aspiration must be followed in the office as is observed in the operating room. If, as too frequently happens, this is impossible, the aspiration of the knee or any other joint should be a hospital procedure. It is well to have this late case report after one week, when the bandage or strapping is removed for the administration of heat (diathermy, infra-red lamp, electric baker, hot fomentations, local leg bath, or hot whirlpool bath), massage, and guided active exercises. The same measures may be necessary in the acute case if there is still evidence of pain and some stiffness after he is allowed out of bed.

Operation.—Following operations for removal of the semilunar cartilages, most authorities on this subject advise splinting for a period of two to six weeks. It is the practice of many surgeons following this operation to apply a plaster cast for a similar period. The splinting or cast accounts for many of the cases of partial loss of function, so commonly seen following semilunar cartilage operations.

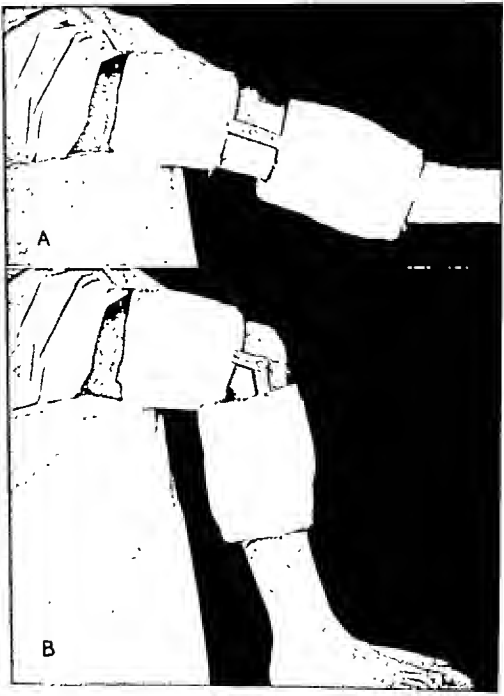

FIG. 18.—*A*, hinged plaster of paris cast allowing flexion and extension movements of the knee joint; *B*, same as Fig. 18, a.

Massage, Heat, Exercise.—Massage of the muscles of the lower leg and of the thigh start early, but no massage is given directly over the knee joint until the wound is healed, thus preventing the danger of infection. The exception to this is the massage given by the surgeon himself when dressing the wound. At least two or three times during the first nine days the dressings are removed from the knee, and the surgeon, with his hands protected by sterile gloves, can swab the entire area of the knee joint with alcohol and massage the popliteal space, move the patella, and otherwise give a fairly good massage to the joint proper. Massage of the upper and lower extremities can be left to the technician. After the tenth day, when the wound has healed, heat, massage, and active exercise can be given in increasing doses. By the end of the third week these patients can be discharged, usually with 75 to 100 per cent of joint function present (Fig. 27). If necessary, the physical therapy treatments should be continued until full joint function has been secured. This can usually be done after the patient is ambulatory and has left the hospital by having him report either to the surgeon's office or to the physician specializing in physical therapy.

This mobilization treatment, modified as necessary to meet special cases, can be employed in most operative conditions for the removal of joint mice, fat pads, following synovectomies, and similar conditions.

In addition to the active motions herein described, the surgeon must make sure that free movement of the patella is present or is improving daily.

INTRA-ARTICULAR INJURIES

There are *intra-articular injuries* which may require prolonged immobilization, viz., stretching or rupture of the crucial ligaments; fracture of the tibial spine or of the tibial articular surface, with displacement; and, finally, dislocations of the knee joint. It is difficult for a surgeon to write of joint trauma without going into too much detail concerning the actual nonoperative and operative treatment of the condition. The length of this chapter reminds me that I have already indulged this tendency in other joint conditions. The purpose of the chapter is to deal with the prevention and, when necessary, the restoration of function in these disabling joint traumas.

DISLOCATION OF KNEE

Reduction.—A dislocation of the knee requires immediate reduction followed by complete rest and immobilization. The crucial and lateral ligaments are always torn. Operative procedure for the reduction is not necessary. Immediate operative repair of the crucial or lateral ligaments is never indicated. There is often damage of the joint cartilage surfaces when a complete dislocation occurs. For this reason, after reduction is secured, I prefer to keep the patient in bed with a

lost. Therefore, massage of the thigh and leg muscles and the use of a faradic or sinusoidal current to keep up muscle tone are most definitely indicated during the weeks of immobilization.

Operative Procedure.—In the case of undue lateral or anteroposterior movement, I prefer to continue the wearing of the immobilizing appliances for at least six months before considering operative treatment on the crucial ligaments. If there is evidence that the disability is due solely to a torn internal lateral ligament with semilunar cartilage displacement, earlier operative procedure may be indicated.

Physical Therapy.—In the case of a partially stiff knee joint after the cast or immobilization appliance is removed, I prefer slow, gradual physical therapy methods to overcome the condition rather than forcible manipulation. The latter can easily undo all the advantages gained by prolonged immobilization.

TORN LIGAMENTS

Immobilization.—Torn lateral ligaments and stretched or ruptured crucial ligaments are treated in exactly the same way as described for dislocation of the knee. Prolonged immobilization gives good functional results in the majority of these cases. Many of the cases which require operative procedure are those in which the diagnosis of damaged ligaments was never made and, therefore, the period of treatment was not sufficiently prolonged. After the acute symptoms have subsided, or after recovery from a semilunar cartilage operation (for many of these have been operated on for this condition), the patient is urged to walk and exercise his knee. His complaints of weakness, of falling, or other queer complaints were ascribed to a neurosis. Finally, such a patient is referred for reconstructive surgery. Complete diagnosis of the original trauma with sufficiently prolonged treatment might have resulted in a cure without the need of surgery.

Tears of the lateral ligaments are better treated with the leg in complete extension. Tears of the crucial ligaments are better treated with the leg in 15° to 20° of flexion. Since it is difficult to determine which of these groups of ligaments has been more severely damaged, the dislocation of the knee should be treated with the leg either extended or very slightly flexed. If no dislocation has occurred and the nature of the accident was not too severe, the extension position is indicated; but if a definite diagnosis of torn crucial ligaments is made, a position with 10° of flexion is indicated during the period of immobilization. The same physical therapy measures outlined for dislocations are indicated in the treatment of these torn ligaments.

The anterior crucial ligament is more often stretched or ruptured than the posterior. When the lower leg is partly flexed and a sudden force on the outside of the knee or a fall of the body inward causes

Thomas splint and light traction on the lower extremity to keep the joint cartilages slightly separated.

Splintage and Traction.—The Thomas splint either is bent at the knee or is padded under the knee to give approximately 10° of flexion. In slight flexion the crucial ligaments are more relaxed, and even though light traction is maintained for two weeks, these ligaments are not unduly pulled away from their normal locations. There is a tendency for flexion deformity to occur in crucial ligament injuries, and this, of course, is to be guarded against. Let me emphasize that heavy traction is not desired, but 15 lb. of traction will keep the joint surfaces slightly separated, and slight shrugging movements or the slight movement accompanying massage combined with this will prevent arthritis following the damage to joint cartilages. Traction and rest in bed furnish likewise the rest and immobilization that are desired and should be kept up for at least two weeks. The further advantage of traction treatment, as compared with the immediate application of a cast, is the ease with which the accompanying effusion can be treated by heat, hot fomentations, or aspiration, if necessary. During these two weeks of traction, heat, massage, and especially manual manipulation of the patella to keep it free and movable, can be administered.

Plaster Cast.—After two weeks of light traction treatment (or longer if the swelling and reaction in the knee have not subsided), immobilization of the knee joint by a plaster cast or a special knee appliance should be instituted with the leg almost completely extended. With the application of the cast, the patient can be allowed up on crutches. After four to six weeks, light weight-bearing may be allowed. The immobilization should be continued for approximately 10 weeks. If, at the end of that period, there is still evidence of undue lateral or anteroposterior movement, continued immobilization is indicated, but usually at this stage a hinged two-piece plaster cast can be utilized or a special hinged knee brace can be worn (Fig. 28). The latter is preferable, as it can be removed for heat, massage, and carefully guided exercises by the surgeon or a trained technician, who should always guard against undue lateral or anteroposterior movements. Frequently after the removal of the cast the knee joint is fairly stiff.

Manipulation.—The stiffness is often due to a fixed patella. To prevent this, the front of the cast should be cut out shortly after the cast is applied, and the patella massaged and manipulated daily. The patient can often be instructed to shrug his muscles and otherwise keep the kneecap movable.

The stiffness may be due to contracted muscles. Often, however, the muscles about the joint have become badly atrophied so that the strong muscular protection of the joint against undue movement is

massage, and slight active exercises. At the end of five weeks the patient was discharged but was placed in a hotel rather than allowed to return to his home in a distant city. Daily he went from his hotel to the physical therapy laboratory, where carefully supervised treatment was given. By the end of six weeks, complete extension was allowed and flexion movements were actively performed until the pain point was reached. Heat, the whirlpool bath, massage, and walking exercises, such as walking up a gradual incline and, later, the climbing of very low steps, were gradually added to the treatment. After 10 weeks no protective splints or appliances were used. At the end of four months I demonstrated this case before the Chicago

FIG. 19.—*A*, case of torn anterior crucial ligament showing the incision for reconstruction of the ligament from fascia lata; *B*, same case as Fig. 19, A, showing the amount of knee flexion obtained by this patient five months after the operation.

Surgical Society. He had 45° of flexion and a perfectly stable knee joint, and walked readily without a cane. He stepped up on a chair in order to show his knee to the audience. In doing this he put the foot of the injured leg on the chair first and raised himself with this leg.

It is my opinion that in younger men with many years of active work ahead of them this operation, followed by a careful physical therapy régime, is indicated when a loose knee joint is the alternative.

a sudden abduction of the tibia with internal rotation, the anterior crucial ligament is usually ruptured. When the leg is partly flexed and the sudden force causes an adduction of the tibia, possibly with external rotation, the posterior crucial ligament may be ruptured. Usually this force causes a fracture of the internal articular shelf and tuberosity of the tibia and this fracture probably allows sufficient give in the joint to protect the posterior ligament from complete rupture. When the leg is almost completely flexed and the foot fixed and a strong inward force is applied at the knee, the tibial spine usually fractures, the anterior crucial ligament stretches or ruptures, and the external shelf of the tibial articulation may be fractured.

These combinations of fractures and ruptures of the crucial ligaments, especially the anterior ligament, must always be kept in mind. The x-ray is always indicated in knee injuries even of minor degree, and thus the fracture is discovered. Immobilization and the physical therapy measures described under dislocations are the treatment of choice here. If the fractured fragments interfere with joint movement after every effort by closed reduction has been exhausted and after the traumatic reaction in the knee has subsided, operative replacement or removal of the obstructing fragment of bone is indicated.

CASE II.—A year ago a patient was referred to me for reconstructive surgery. Eight months before he had stepped in a hole small enough to incarcerate his foot, had fallen forward, thus bending the knee, and at the same time he had fallen inward due to the falling of a heavy jack, used under a locomotive engine, against the outside of his knee. He had been treated with a cast to the knee for six weeks. Following this he used crutches and attempted to use his knee. Instead of improving he developed weakness, undue lateral and anteroposterior motion, and inability completely to extend his knee. It was more comfortable in a flexed position. A hinged knee brace was applied after six months and this enabled him to walk, but without it the knee was so unstable that he was crippled. Figure 29 shows a patient following a reconstructive operation which I performed, utilizing fascia lata to reconstruct a new anterior crucial ligament which had been partially torn and so stretched that it was useless. This operation is described most completely by Jones, the original operation being ascribed to Hey Groves.

The question of prolonged immobilization following this operation was considered, but it seemed to me that early function of the knee joint would help strengthen this fascial replacement and cause it to assume ligamentous function. Therefore, the patient was placed in bed with the leg in a Thomas splint and the knee flexed about 10°. Massage of the leg and thigh muscles, which were atrophied, was started at once, the incisions being carefully protected. The patient was instructed to shrug his muscles and after the fourth day the patella was carefully moved laterally to keep it free. This was repeated at each dressing. All stitches were out by the end of two weeks and the wounds healed, thus allowing more active massage. At this time very slight active motion of the knee joint was permitted. At the end of three weeks a posterior splint was applied with very slight flexion and the patient was allowed up on crutches. He reported to the technician for daily heat,

When these fractures occur with little or no displacement, a short period of complete immobilization, followed by mobilization and physical therapy, usually results in excellent function. Great care must be taken to discover comcomitant injuries which may nullify efforts at functional restoration.

I usually keep such patients in bed for one week if there is marked effusion or hemo-arthrosis present. The leg is protected in a Thomas splint and by traction. Aspiration is done if necessary. As soon as feasible, a posterior plaster splint from the mid-thigh to the ankle is applied and the patient is allowed up on crutches. Massage and movements of the patella are given. After two weeks the splint may be removed for heat, massage, and *very slight* active exercises. After four weeks, more definite slight flexion and extension can be permitted. Weight-bearing, at first aided with crutches, can start at the end of six weeks, and by the end of eight weeks, full weight-bearing and 50 per cent of flexion should be present. Physical therapy is continued for another two weeks, by which time full function is usually restored.

Where there is marked displacement downward with a very definite offset in the articular surface, operation is indicated, first to replace the fragment and, if this is impossible, to insert a wedge of autogenous bone which will reconstruct the joint. Following this the line of treatment is carried out as above, except that each step is delayed approximately two weeks.

Fractures of the head of the fibula are the most frequently overlooked fractures in the body. They often occur with Pott's fractures. The latter give very definite signs and symptoms and the x-ray is confined to them. The fracture in the head of the fibula is not discovered until the patient's complaint of knee pain and loss of knee function attracts the surgeon's attention, usually weeks later. Therefore x-rays should always include adjacent joints in fractures of an extremity.

Fractures of the patella are one of the commonest causes for loss of knee-joint function. Those due to marked contracture of the quadriceps, or due to direct injury, with little displacement, can be treated conservatively. Strong fibrous union of the fragments which are even slightly separated seems to give good functional results.

Operative procedure: A fractured patella with definite separation of the fragments is better treated by operative procedure. The technic will not be discussed except to say that I am securing a good union just as rapidly by the simple procedure of coaptating the fragments and then using mattress sutures of either No. 2 chromic catgut or a very small kangaroo gut placed through the patellar tendon, periosteum, and aponeurotic covering, above and below the site of fracture, to hold the fragment in position.

FRACTURES

Periarticular-articular traumas of the knee joint which require special mention are fractures which extend into the articular surfaces, often resulting in permanent loss of function.

A T-FRACTURE THROUGH THE CONDYLES usually shows a marked backward displacement of the distal fragment of the femur with separation of the fracture line between the condyles. Occasionally one or the other condyle may be partially rotated. As nearly perfect alignment of the condyles as possible is necessary for good function. At least 50 per cent of coaptation of the fractured fragments of the femur is sufficient to give good function. Better approximation than this is, of course, desirable, but failure to secure it does not warrant open operative reduction. I mention this because I have seen far fewer good results in knee function from operating on this fracture than I have seen when the closed method is used. Manipulation, usually with strong traction on a Hawley table, or the slower method of skeletal traction, will reduce such fractures. The application of the ice-tong type of skeletal traction will tend to squeeze the fractured fragments of the condyles together. A Thomas splint with a knee attachment allowing flexion of the lower leg is used and is far preferable to the application of a thigh and leg cast with the necessary immobilization of the knee. A Blake skate or a similar splint fastened to the sole of the foot keeps the foot at right angles and serves even a better purpose. To this splint is attached a rope which passes upward to a pulley on the fracture frame located just above the knee, then passes through a second pulley just above the patient's chest, and hangs downward from this pulley with a hand loop in the end of the rope. The patient is taught to grasp this rope, and by pulling and relaxing it, he lifts and lowers his foot and leg, thereby maintaining a large amount of flexion and extension in the knee (see Fig. 2). This can be done without disturbing the fracture position. It is applicable to all fractures in the shaft of the femur when skeletal traction is used and is one of the best means of maintaining knee function. Combined with it should be massage of the entire leg. Any method which will do away with the prolonged immobilization of the knee in extremity fractures with the weeks and weeks of treatment necessary to overcome the resulting stiffness is to be greatly desired.

FRACTURES OF THE TIBIAL TUBEROSITIES often extend upward and inward into the joint. The fractured fragment is often displaced outward or is accompanied with comminution and a marked downward displacement, thus giving a decided offset to the articular table of the tibia. This latter condition usually occurs on the internal aspect of the joint. It results in an adduction deformity of the tibia and a rocking, unstable knee joint.

He wears his splint when walking and at night for one to four weeks more, depending upon the x-ray findings, the strength of the leg, and the progress toward flexion function thus far made.

Seldom is any splint or mechanical appliance necessary after 10 to 12 weeks. By this time the average patient is able to flex his knee almost to a right angle. Further physical therapy is not usually necessary, as the patient has been trained by this time to perform exercises which will improve function. For most of them return to work is the best form of occupational therapy to use. I keep in touch with the patient until he can kneel and sit on his heels, both movements showing that function has been restored.

Complete loss of the patella occurs rarely in civilian life. It may follow severe extensive wounds, as a gunshot wound where the kneecap is shot away; or a severe infection with a complete sloughing of the patellar tendon patella, and tissues at the front of the knee; or, as in one of my cases, it may follow a sloughing without evidence of infection.

Case III.—Mr. H. was a railroad case sent to me from Ohio approximately one year ago. Some eight months previously he sustained a fracture of the patella with separation of the fragments and was operated upon, chromic gut being used to approximate and hold the fragments. After a time the fragments separated, he was again operated upon, and the fragments were approximated and held by the use of wire. The first operation was done by a median longitudinal incision and the second, by a U-shaped incision. Nonunion and separation of the fragments again developed, and a third operation was performed in which most of the wire was removed, although one loop was left attached to the lower fragment. This approach was by a lateral, longitudinal incision. He was referred to me for an ununited fractured patella. The fragments were separated approximately one inch. The patient complained of pain, a sense of weakness in the knee joint, and only about three degrees of flexion movement in the knee. Here is an important point: I did not give sufficient thought to the disturbed circulation in the tense skin and aponeurotic tissue overlying this patella. I operated, exposing the patella, by a second U-shaped incision. The fragments were freshened along their fractured edge, the loop of wire was removed, and then the fragments were drilled and kangaroo gut was inserted through the drill holes, forming two strong mattress sutures, approximating and uniting the fragments. The thickened patellar tendon and aponeurosis were then sutured over the fragments with chromic catgut. The wound was closed and the knee immobilized by a posterior plaster splint with the leg in complete extension. Within four days the margins of my incision were black and gangrenous and the skin sutures sloughed out. The skin flap above the patella retracted, exposing the aponeurosis over the patella, which was likewise gangrenous and sloughing. In spite of every effort to stimulate circulation in these flaps, all the soft tissues over the patella became gangrenous and either sloughed or were cut away with scissors. The patella itself was finally completely exposed, and within a month it was evident that the

After-treatment: So many different opinions are expressed by authors concerning the after-treatment of these fractures that the average reader is often at sea. Recently I have seen the stopping of all immobilization at the end of six weeks advocated. Jones advocates the wearing of protective splints for as long as six months. I believe the various views depend upon the seriousness of the injury, the amount of displacement of the fragments, and the operation.

Badly comminuted and markedly displaced fractures probably require longer immobilization than do milder types. Fragments maintained in position by wire passed through drill holes have good internal splintage and therefore probably do not require such prolonged external splintage. I personally prefer longer external splintage to hardware over the patella.

In the average case—and there are many modifications of this, depending upon the case—I apply a padded posterior splint from the mid-thigh to the ankle immediately after operation.

Early massage of the thigh and lower-leg muscles without removal of the splint is started within three days.

The wound over the patella is dressed every other day after the third day, with gloved hands, chiefly for the purpose of light manual movements of the patella to prevent infra-patellar adhesions. After removal of the stitches, the massage is given over the knee joint and the movements of the patella are increased.

After two weeks the posterior splint is removed for massage of the entire thigh, leg, and knee joint, but no movements of the knee are allowed. After reapplication of the splint, the patient can be allowed up on crutches, but no weight-bearing is permitted.

The patient may now be discharged from the hospital, or, if he can afford it, he is kept for further physical therapy treatment. If discharged, arrangements must be made to continue the removal of the splint and massage at least every third day. Walking with the injured leg swinging furnishes good exercise.

At the end of four weeks, shrugging of the muscles within the splint or during the massage treatments is allowed, and very active foot exercises and the swinging of entire leg are started.

At the end of six weeks very gentle active exercise is allowed when the splint is removed for massage. At first only 2° or 3° of flexion are permitted. This amount of flexing and extending is repeated several times and the splint is then replaced. Daily or every other day for another three weeks the patient reports and the amount of flexion and extension exercises is increased until 30° to 40° of flexion are obtained. By this time the patient is walking with the aid of only a cane, or possibly with no assistance.

After eight weeks the patient is allowed to remove his splint several times a day for the application of heat, rubbing the knee, and active exercise. He can be trusted not to overflex it and, in fact, must often be urged to stand a little pain and flex it more and more.

Such a knee as this incapacitates a man for heavy work. It is possible that he could carry on many heavy occupations if he wore a cage splint made of leather and side steel braces, partially hinged at the knee joint. It is possible that a reconstructive operation might be beneficial in the average case, but neither the patient nor the surgeon was willing to risk further incisions in this area of frequent operations and disturbed circulation.

Physical therapy for the purpose of overcoming muscle atrophy and of securing 10° to 20° of flexion in such a condition of complete loss of the patella offers the best chance of partial function.

A DISLOCATION OF THE PATELLA, partial, is not uncommon, but complete dislocation of the patella is comparatively rare in civilian practice. The latter is often followed by recurrent dislocations.

For partial dislocation or the first complete dislocation, manual reduction, followed by three to six weeks' immobilization of the knee in extension, is indicated. During this period of immobilization every effort should be made to strengthen the quadriceps and the patellar tendon by removing the immobilization apparatus daily, or every other day, the leg still being held in complete extension, and massage and muscle stimulation being administered by faradism or the sinusoidal current.

In recurrent dislocations the patient should be operated upon. Several operative procedures have been described. They consist of either increasing the flange on the external condyle of the femur or shortening and fixating the patellar tendons into the antero-internal margin of the tibia, or a combination of both. The dislocation is usually outward and would undoubtedly occur more frequently were it not for the fact that "the outer margin of the trochlearis surface of the femur acts as the flange of a pulley-wheel and so offers resistance to the outward deviation of the patella." (Jones.)

STIFF KNEE JOINT FOLLOWING INJURY may be either fibrous or bony. An x-ray is always indicated to differentiate the type of stiffness. Frequently there is a combination of fibrous and bony ankylosis or, if the treatment of the stiff condition is too strenuous, the fibrous ankylosis may be changed into a partial or complete bony ankylosis.

Following the treatment of fractures in the upper extremity, in which the knee has been immobilized and the extremity completely out of use for weeks and months, the fibrous stiffness involves fibrosis of atrophied muscles, contracted fibrotic changes in the patellar ligament with fibrous adhesions in the infrapatellar space, contracted ligaments and capsules, agglutination of the surfaces of the bursa with fibrous changes, and agglutination or thickening of the synovia.

Frequently the surgeon is tempted to hasten function in such a knee joint by forcible manipulation. The atrophied, fibrosed tissues have lost their normal elasticity and will therefore tear rather than give

fragments of the patella were dead and were simply two shriveled, foreign bodies lying loosely within the wound. Finally, during the dressings the fragments of the patella were lifted from the wound even without being cut away. In other words, the blood supply had been so disturbed that, without any evidence of infection, gangrene of the soft tissues and of the patella at the front of the knee developed, and when all were finally trimmed away, we had a knee joint covered by thick, fibrous infrapatellar tissue, the patella completely gone, and the patellar tendon absent a distance of five inches, a large, raw area filling in by granulation tissue and occupying a space of some four inches in length and three inches in width over the anterior aspect of the knee. After the patella had been removed, this area filled in rapidly with granulation tissue, and the skin grew in from the margins, so that a skin graft was not necessary. The patella was replaced by thick, fibrous tissue. Heat, massage, and exercise of the lower extremity

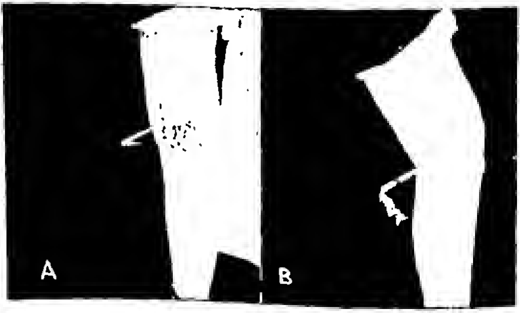

Fig. 30.—*A*, complete loss of patella; *B*, amount of knee flexion secured by patient in Fig. 30, a.

were persisted in during and after the healing period. The knee was protected for a time by a cage splint, but as long as this was worn, the atrophy of the quadriceps and other muscles about the knee joint persisted. Finally, all knee splintage was removed and the patient was instructed to walk and use the leg as much as possible. I saw this patient a month ago, or some eight months after the wound had completely healed. He had approximately 10° of flexion at the knee. He had good strength in the leg for walking on level surfaces. If he stepped on a stone or other object on the ground, the knee seemed weak and he had a tendency to fall. His greatest complaint was of weakness on attempting to climb stairs normally. He could go up two steps at a time provided there was a banister to which he could hold and help pull himself up (Fig. 30).

In some of these crushing injuries, the quadriceps muscle and tendons may have been so damaged, and the scar tissue may so involve the capsule and ligaments, that a stiff knee joint is inevitable. Here judgment must be used relative to the length of the physical therapy treatment. It is silly to prolong massage and attempted flexion and extension exercises when the very nature of the injury and the associated resulting conditions within and about the knee joint mean that a stiff knee will result.

Thick, fibrous pads within the capsule and within the joint proper seldom yield to forcible manipulation under anesthesia. Personally, I have seen so many disastrous results in marked fibrous ankylosis, following forcible manipulation under anesthesia, that I do not believe description of the method is indicated here. Physical therapy, heat, massage, and assisted active and active exercises should be persisted in daily, as described above, as long as there is hope of improvement.

Mechanical traction and slow, forceful mechanical flexion by means of various types of apparatus are often helpful in this type of knee joint. In addition to the flexion traction described above, one may apply gradual forcible flexion by means of turnscrews fastened into a cast applied around the thigh, and a second cast applied around the lower leg and foot. Another method is applying a cast to the entire lower extremity and bivalving it at the knee, cutting out considerable distance of the cast in the popliteal space. Wedges are then gradually placed between the bivalved margins of the cast over the patella. The gradual separation of these margins causes knee-joint flexion.

Jones describes Turner's appliance for this gradual forcible flexion thus: A plaster of paris cast, well padded, is applied over the thigh, and a second well padded cast is applied over the foot and lower leg, leaving the knee joint exposed. Turner's appliance consists of an instrument that resembles ice tongs but with the distal prongs elongated into strong bands that can be incorporated into the lateral or medial sides of the above-mentioned plaster casts. A turnscrew rod joins the opposite arms of the ice tongs. The handle of the turnscrew points upward toward the patient. By increasing or decreasing the distance between the proximal ends of the arms by revolving the turnscrew, the patient can cause a certain amount of flexion or extension through an activating force carried to the distal arms encased in the casts. This appliance may be attached to one side of the cast, but two appliances attached on either side give more even force (Fig. 31).

The stiff knee joint may be fixed in a flexion position. This is far more disabling than a stiff knee joint in the extension position. The same methods of physical therapy as are used in fibrous ankylosis are required to overcome the condition. Traction applied for the

when forcible manipulation is applied. A marked traumatic reaction develops in the joint and practically always increases the disability. The swollen, acutely traumatized knee is entirely too painful to tolerate movement. The effusion and hemorrhage that accompany the swelling predisposes to more fibrosis. Even if some flexion is obtained, the atrophied fibrosed muscles and the contracted, thickened, weakened ligaments lack the power and function to maintain this flexion.

Physical Therapy.—Prolonged physical therapy offers far greater hope for restoration of function than does any other treatment.

If there is no active infection, but a swollen, somewhat painful knee is present, diathermy is one of the best means of relieving this condition. If possible, it should be immediately followed by massage and very slight assisted exercises.

Heat.—The application of various forms of heat, followed by increasing doses of massage (at first stroking but soon changed into a kneading or effleurage and especially aimed at loosening up the adhesions about the patella), and by assisted active and active exercises, should be given daily.

Exercises.—Exercises which are performed by the patient are far better than passive exercises. The latter are soon changed into efforts at flexion manipulation by the surgeon or technician and are frequently carried beyond the pain point, followed by a traumatic reaction which tends to undo the advantages thus far gained by physical therapy. After four or five weeks of treatment, the surgeon may attempt gentle, but somewhat forcible, flexion manipulations once or twice a week. By this time, he knows the patient and knows how much pain he can stand or how much he assumes complaint of the pain. Never, however, should such forcible manipulation be carried to the point of tearing fibrosed tissues.

Splints and Weights.—The application of mechanical means to secure flexion may be adopted provided there are no traumatic reactions within the joint. For example, the thigh may be suspended in a Thomas splint at a 45° to a 60° angle. A hinged knee piece may be applied to the Thomas splint just below the knee and the leg supported in this. Weights may then be attached either directly to the leg or to the end of the hinged arm of the Thomas splint after the leg is bound to this arm, and by means of the weights, slow, gradual flexion may be obtained. By the use of pulleys and weights, other forms of flexion traction may be applied. This method must be observed carefully to prevent traumatic reaction within the knee joint and should always be accompanied by massage and periods of active exercise, especially extending and flexing the leg to maintain the amount of movement thus far gained. Some of the appliances described later may likewise be used.

Fibrous Ankylosis may follow severe crushing injuries of the knee joint, intra-articular injuries, and operations within the knee joint.

eral fibrous bands not sufficiently foreshortened or not strong enough to give the picture of stiff knee described above.

Every surgeon interested in joint trauma should obtain the little book on manipulative surgery written by A. G. T. Fisher. In this book the author describes the indications and methods for manipulation in the knee joint.

Following a few less serious injuries to joints, pain and slight swelling, and especially pain on certain movements, will persist. These patients are frequently classed as neurotic because the physical examination is negative. Usually such a joint is the seat of a contusion, often accompanying a complete or partial luxation, a sprain, or a contusion of the soft parts over the joint. The original trauma has been relieved and the surgeon becomes disgusted with his patient for still complaining of pain. These obscure conditions are usually the result of adhesions in or about the joint. We expect scar tissue, that is, a fibrosis, in lacerations and open wounds which we can see, but we seem to overlook the fact that contused, lacerated soft parts below the surface undergo a similar fibrosis.

Manipulative Surgery.—Manipulative surgery in these cases offers splendid results. Careful study of such a joint will reveal the location of the adhesions, first, by the point of pain on movement; second, by a definite point of tenderness; and third, by a certain limitation of motion in some one direction, which is constant. Manipulation, usually with the patient awake, aimed at the breaking of these adhesions and the overcoming of the restricted motion, is the first essential, followed by daily movements of the joint to its full limit in all directions to prevent the reforming of adhesions. Physical therapy following manipulation is essential in most cases.

Bony ankylosis is common. Intra-articular injuries, followed by a septic infection within this joint, usually result in bony ankylosis. Failure to make an incision adequate for drainage of the joint, the introduction of drainage tubes within the joint, and immobilization of the joint by plaster splint or cast are more often the causes of bony ankylosis than is the invading organism. The importance of traction with daily mobilization cannot be too often emphasized.

Injuries which cause damage of the cartilages within the knee joint are frequently followed by bone-cell proliferation and a joint synostosis.

Occasionally bony ankylosis is due to a displaced fragment of a fracture with malunion, the fragment acting as a mechanical bony obstruction to joint movement.

Operative Procedure.—Operative treatment of these conditions must be considered. In the last-described condition, the bony obstruction can often be removed, with a good functional result following.

purpose of the gradual, forcible increase of extension is usually indicated.

The hinged appliance with the upper and lower arms of the appliance connected by a turnscrew can be firmly attached to the posterior aspect of the thigh and leg and then, by the gradual turning of the screw, the amount of extension can be forcibly increased.

Whenever gradual, forcible flexion or extension devices are used, they should be removed frequently for inspection of the joint to ascertain if a traumatic reaction has followed these maneuvers, or to ascertain if the knee is gradually returning to its original fixed position. If the amount of movement gained by gradual forcible flexion or extension is lost after removal of the appliance, it usually indicates a traumatic reaction. When this is present, mechanical force should be abandoned for the slower but surer methods of physical therapy.

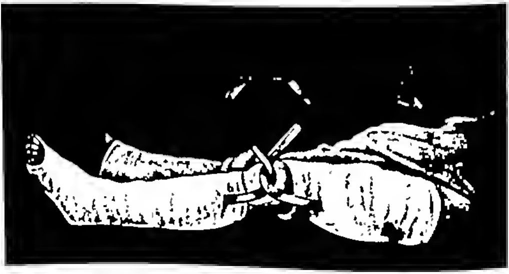

FIG. 31.—Turner's appliance for gradual forcible flexion of the knee. (From Sir Robert Jones' "Orthopedic Surgery of Injuries.")

Frequently following injuries to the knee joint, usually of not so serious a nature, and frequently following operations, as for the removal of semilunar cartilages, the patient will complain of a certain amount of *stiffness within the knee joint*, or of pain when flexion or extension movement passes a certain point, or of a sense of slight locking, sudden giving, or jerking sensations within the knee joint on movement. Frequently these are not noticed when he is around on the leg during the day, but after retiring, when the leg is relaxed, he will notice these sensations within the knee joint and they will usually be followed by pain.

Practically always the above symptoms are associated with *adhesions within the knee joint*. These are usually single adhesions or sev-

Physical therapy is indicated in these cases for the purpose of overcoming muscular atrophy and maintaining the strength of the quadriceps muscle. This can be accomplished by massage, leg exercises, and faradism to the quadriceps.

Positions of Function.—When, following knee-joint trauma, loss of function is threatened or inevitable, the surgeon must guard against faulty positions of stiffening and make sure that when the patient does recover, he will have the greatest possible usefulness in the damaged extremity.

I recently talked with a number of orthopedic surgeons concerning the best position of ankylosis of the knee joint. Several felt that the leg was most useful when akylosed at approximately a 10° flexion angle. A few others preferred full extension as the best position of function when complete ankylosis was inevitable.

In working men, especially when they must be on their feet all day and considerable walking is involved, I believe the full extension position gives more strength and causes less backache and tiredness in the lumbar region and groins. The slightly flexed position makes the ankylosis less apparent and probably is more comfortable and more useful for the sedentary worker.

The tendency for certain deformities in the knee joint to develop during long periods of immobilization must be guarded against.

As the knee joint is stiffening following severe trauma, there is a tendency for an undue flexion position to develop. A flexion ankylosis beyond a 10° to a 15° angle is extremely disabling.

A genu hyperextension or backward angulation of the knee joint is prone to develop during a long period of rest in bed in lower extremity injuries. Frequent change of position of the knees, and especially flexion and extension exercises, are the best means of preventing this deformity. When this is impossible, a posterior splint or a pad in the popliteal space is always indicated. In placing the lower extremity in a cast, it is better to have a slight degree of flexion present to avoid this danger of hyperextension. When the nature of a trauma calls for a complete extension of the lower leg, the popliteal space should always be padded to prevent hyperextension.

The *concomitant injuries of other joints* in the lower extremity must always be borne in mind in the surgery of trauma. Protection of function in the hip and ankle joint while treating a traumatized knee joint is imperative. The avoidance of flatfoot and the making sure that the foot does not drop below a right angle will be of the greatest assistance in restoration of function in the knee joint.

Ankle Joint and Foot

Loss of function in the ankle joint following trauma is most frequently the result of loss of the dorsiflexion foot function. An ankle

Arthroplasty.—Arthroplasty of the knee joint is indicated only in selected cases. In severe fractures into this joint, with bony ankylosis which has obliterated all signs of the joint surfaces and with the leg in fairly good position, it is never indicated. Stability of the knee joint is the first consideration, and the risk of giving a flail joint in such cases must be borne in mind. In cases of bad displacement, such as a marked flexion of the lower leg with a stiff knee joint, especially in younger individuals, the operation may be performed. Unless one can be quite sure of remodeling a good, firm knee joint, it is better to straighten the leg and allow it to ankylose again in this improved position. In many cases of infection where bony ankylosis has occurred without complete loss of the contour of the joint surfaces, arthroplasty is indicated, but only after several months have elapsed since the active infection has ceased.

In 1919 I observed Dr. Putti, of Bologna, Italy, perform this operation and was impressed with the extreme care with which he remodeled the exact contour of the condyles and the normal depressions in the head of the tibia, followed by a most painstaking relining of the joint by a pedicle fascial transplant. He demonstrated 13 cases operated on in the past, all of which had more than 75 per cent function in the knee joint.

Active and Assisted Active Movement.—Success in these cases since then has been due to the proper selection of the subject, the care exercised in remodeling the articular surfaces, the use of a sufficiently large fascial transplant, long-continued traction, and the early use of assisted active motion to at least 50 per cent of the normal joint movement, followed by active motion in the knee joint after six weeks and associated with physical therapy until the greatest possible function is obtained.

Encouragement of these patients to persist in their efforts to regain function is of the greatest importance. One should make some form of measuring appliance, showing the limitation of motion before the operation and the increase in the amount of motion gained as time goes on. Nothing is so encouraging as actually visualizing the progress in the range of joint movements.

This measurement of joint movement during the period of treatment of any of these old joint injuries is always an incentive to encouragement and coöperation on the part of the patient.

Following certain very severe traumas of the knee joint with marked loss of substance, but more often following attempts at arthroplasty, the *flail knee joint* develops.

Mechanical splints, leather knee jackets, and stationary or hinged splints have been developed for the protection and comfort of these flail knee joints. Operative procedure for the purpose of an arthrodesis is indicated in most of these cases. Prolonged fixation with the leg in the extension position must follow.

Early mobilization of the various joints involved in the ankle and foot is imperative if fibrosis and a certain amount of stiffness are to be avoided. The foot and ankle stand immobilization better than the wrist and hand, due to the fact that these patients are usually up on crutches, are swinging the foot and lifting it into different positions, and frequently bear a certain amount of weight upon the extremity even though it is in a cast. Immobilization with a certain amount of function continued is less disastrous than immobilization with complete absence of function.

The badly swollen foot which results from crushing trauma should be relieved as soon as possible. Hemorrhage under the strong fascia of the foot, if allowed to persist, often results in a fibrosis. We do not see the effects of ischemic paralysis in the foot as often as in the upper extremity. We see the "congealed foot" oftener than the "congealed hand." This usually follows a prolonged persistent swelling, and especially a persistent swelling combined with prolonged immobilization. It always results in a painful foot and is usually accompanied with cyanosis; clammy skin; thickened, hard, swollen tissues; and a stiff, useless foot.

Treatment.—The acute conditions of the foot and ankle and various deformities of these parts are treated in other chapters. Treatment here will be limited to the restoration of function in old disabling conditions following traumas to these joints.

TRAUMATIC ARTHRITIS OF ANKLE JOINT

Traumatic arthritis of the ankle joint occurs in older individuals who usually show a tendency to arthritis in other joints. A severe contusion of the ankle joint in an old individual may result in this condition. The early x-rays are frequently negative and the condition is treated as one of contusion and sprain. At first there may be considerable mobility in the ankle joint, but this gradually decreases, and pain is complained of more and more. After a few weeks a second x-ray is taken which usually reveals osteo-arthritic deposits along the astragalus or tibial surfaces of the joint or an area between the tibia and external malleolus of the fibula. Prolonged immobilization, especially in older individuals, is to be avoided as far as possible. When there is a possibility of joint cartilage injury in these contused, sprained traumas, traction with separation of the joint is essential. Every day, or every other day, the extremity should be released from traction, however, and heat, massage, and active exercise by flexion, extension, and lateral movements should be allowed. Passive movements with the danger of carrying these exercises beyond the pain point is never indicated. Too early weight-bearing frequently predisposes to osteo-arthritis in this joint. However, after the condition is established and stationary, weight-bearing, although painful, should be encouraged. Per-

joint may completely lose its lateral movement and yet, if this power of dorsiflexion of the foot remains, the patient can be comfortable and useful. Loss of anteroposterior movements of the ankle joint, especially in the equinus position, is the most disabling.

Injuries which destroy the normal vertical weight-bearing angle through the ankle joint always result in a certain amount of loss of function. This may follow fractures in the lower end of the tibia and fibula; Pott's fractures, with a backward angulation of the distal fragments, rarely a forward angulation of these fragments; and a fracture through the lower end of the fibula, often resulting in an abduction deformity followed by a traumatic valgus position of the foot. A traumatic varus position frequently follows fractures through the malleoli. All these result in a loss of the vertical weight-bearing angle.

INTRA-ARTICULAR INJURIES

Intra-articular injuries may result in a traumatic arthritis, due to damage to the joint cartilage, a contusion of the joint followed by infection with or without the formation of pus, fractures extending into the joint with a fragment of the fracture protruding into the joint forming this type of arthritis, or partial or complete dislocations of the ankle joint. In the latter, a separation between the astragalus and the external malleolus, often resulting in a valgus position and a partial forward slipping of the tibia on the astragalus, is not uncommon.

PERIARTICULAR INJURIES

Periarticular injuries most often resulting in loss of function are severe crushing injuries of the ankle with fibrosis of the capsule, ligaments, aponeuroses, and tendons; infections following severe injuries in the neighborhood of the ankle, resulting in the same fibrosis; and tears of the lateral ligaments following severe sprains or sprain fractures. The whole condition often results in a weak ankle or turning of the ankle.

The ankle joint and joints of the hind foot and the joints of the forefoot are so closely related in function, and several of these are so frequently involved concomitantly in the injury, that restoration of function usually involves consideration aimed both at the ankle and the foot.

Prevention of Loss of Function.—Every injury in the foot and ankle must be treated from the standpoint of maintaining the vertical weight-bearing angle, the maintenance of a dorsiflexion of the foot to at least a 90° angle, and the preservation of the longitudinal arch of the foot.

A slight varus position of the foot is always to be preferred to a valgus position. Every effort must be made to prevent either of these conditions from developing as a permanent deformity.

least two weeks. During this period the use of diathermy will help relieve the pain and swelling. In the absence of diathermy, hot fomentations or the contrast bath, 12 min. of a hot local foot bath, then 3 min. of a cold local foot bath, or alternating hot and cold fomentations, will all help decrease the marked swelling and reaction about the ankle and foot. A pillow or blanket splint during this period will prevent redislocation and is usually all the splintage that is necessary. From the third to the seventh day, very slight assisted active exercises may be used. During this period, massage of the foot, ankle, and leg, following the direction of the venous flow, and given daily, is indicated. After a week the amount of active exercise can be increased. At the end of two weeks a light, molded boot splint holding the foot always at a right angle and protecting the back and sides of the ankle can be applied and the patient allowed up on crutches. He may now go home and report for physical therapy treatments at least every other day. These consist of heat, massage, and an increasing amount of exercise. At the end of a month, weight-bearing can usually be allowed. The contrast bath used two or three times at home by the patient with frequent periods of rest with the leg elevated higher than the buttock will prevent the swelling of the foot so common in fractures and dislocations in this region. From the fourth to the sixth week it may be necessary to protect the ankle hy a firm bandage or adhesive strapping, but at the end of that period, if the above active treatment has been carried out, recovery is usually complete.

OLD DISLOCATIONS OF ANKLE JOINT

Old complete dislocations of the ankle are seldom seen. Operative procedure is usually necessary to overcome the contracted tendons, fibrosis, and the malposition of the bones when one of these cases of old dislocation is seen. I have had only one such case.

Old partial dislocations with loss of function are not uncommon. Closed manipulation with a Thomas wrench will usually overcome lateral or medial partial dislocations. This should be followed by from two to six weeks' immobilization in a foot splint. The latter should be removed daily, or every other day, after the third day for hot contrast baths, massage, and assisted active and active exercises. Occasionally I put on a cast with walking calipers and do not remove it for three weeks. Every effort must be made to prevent fibrosis within the ankle joint or foot joint by maintaining mobility and exercise to as great an extent as possible.

Anteroposterior partial dislocations of long standing may be reduced by closed manipulation under anesthesia. If this fails, however, operative interference is necessary. Occasionally a tenotomy on the tendon Achilles, combined with closed manipulation, will overcome the deformity. Here, again, the same sequence of physical therapy to restore function is indicated.

sistent use of heat, massage, and exercises, combined with weight-bearing, will often gradually smooth the small osteo-arthritic deposits so that walking can be performed without pain.

PURULENT ARTHRITIS OF ANKLE

Purulent arthritis or direct infections of the joint from compound fractures into the joint, compound dislocations, or direct injuries always require adequate drainage if pus forms. Drainage tubes into the joints are not indicated. They may be placed down to the joint. Bilateral incisions with drainage down to the joint may be necessary, but

FIG. 32.—Case of purulent arthritis of ankle joint.

a through-and-through drainage tube practically always means erosion of the joint cartilage. Frequent active movements of the joint are indicated during this period of drainage (Fig. 32).

DISLOCATIONS OF ANKLE JOINT

Dislocations of the ankle joint are to be reduced at once. Prolonged immobilization in a cast following reduction is never indicated, even though the application of a cast to the dislocated foot will allow the patient to be up and around on crutches. After reduction of the recently dislocated ankle, the patient should be treated in bed for at

are seldom markedly displaced. Rest in bed and traction to keep the joint surfaces separated, combined with heat, massage, and early active motion, will usually give a good functional result.

DISLOCATIONS OF ASTRAGALUS

Dislocations of the astragalus are not uncommon. Cotton describes eleven different varieties of this injury. It is frequently accompanied with open lesions. Marked damage to tendons and to the ligaments of at least four of the foot joints usually accompanies this dislocation.

Effort should be made to reduce these dislocations by the closed method as soon as they are seen. Reduction may be aided by the Thomas wrench. Failure at closed methods should be followed by an attempt at open reduction. Pressure of the dislocated bone upon the soft tissues soon results in sloughing and infection. The latter is a serious complication in this condition. Therefore great effort must be made not to damage unduly the tissues during the attempt at closed reduction, and failure of this method should be followed at once by an open arthrotomy. If the injury is a pure dislocation and no fracture is present, it can usually be reduced. Complete removal of the dislocated astragalus is sometimes necessary, but it should be avoided when possible. If it is complicated with fracture, it is almost impossible to reduce the dislocated fractured fragments, and its removal is therefore necessary. Never should pressure necrosis and the dangers which follow this be allowed to develop from leaving a dislocated fragment of the astragalus intact.

Following reduction, redislocation is very rare and need not be greatly feared during the active treatment of the condition. Mobilization of the foot with heat and active movements are far to be preferred to immobilization by cast treatment. Great attention must be paid to the protection of the badly contused, often partially necrosed soft tissues. Figure 33 illustrates one of my cases in which the dislocated astragalus was replaced, this treatment being followed by early use of heat, massage, and active exercises. The result was the complete restoration of function within six weeks.

FRACTURES OF THE TARSAL BONES

Fractures of the os calcis, astragalus, scaphoid, cuboid, and any of the cuneiform bones seldom occur without a certain amount of damage in the adjacent joints of the foot. Much of the pain and disability which follow fractures of the os calcis are due to associated joint injury in the astragalus-calcaneus joint, either the result of the trauma or the result of the prolonged treatment of this fracture.

Fractures in the bones of the foot necessarily require a certain amount of fixation. Every effort should be made for the best possible re-apposition of these fractured fragments, otherwise painful foot may

FRACTURE OF MALLEOLUS

Fracture of either malleolus with marked separation between the malleolus and astragalus may result in a gradual valgus or varus position when weight-bearing is allowed. Reposition of these malleoli to a position as nearly normal as possible is therefore indicated in all such fractures. As a rule, in the marked displacement of the malleolus following fracture, especially the internal malleolus, I make a small semilunar incision over the anteromedial aspect of the ankle joint, avoiding the tendons and exposing the fractured fragment. The displaced malleolus is pushed or hooked up into its normal position, the fractured surfaces being carefully approximated. Two mattress sutures of No. 2 chromic catgut are then applied through the fascia and periosteum of the fractured fragments and tied, thus holding them in close apposition. A second line of continuous catgut is sewed through the torn fascia to strengthen this fixation and the wound is closed without drainage.

In addition to the advantage of replacing this fractured fragment, a large amount of old blood and blood clots is evacuated from within the ankle joint. I have performed this operation some eight or ten times, and in every case there is always a marked hemo-arthrosis. These patients recover more rapidly and with better functional results than do those whom I have attempted to treat by the closed method. It is indicated only when there is marked displacement of the malleolus. When these cases are treated by the closed method, aspiration of the hemo-arthrosis is indicated, if, as often happens, there is marked swelling of the ankle joint.

A boot or stirrup splint with the ankle slightly inverted is applied following either the closed or open method of treating these fractures. If the external malleolus is involved, a straight position of the foot is preferable to inversion. Extreme inversion as formerly practiced is seldom necessary. From three to seven days following the application of the splint, it is removed, and massage of the foot, ankle, and lower leg is given. This is repeated daily or every other day until the tenth to the fourteenth day. By this time the wound is healed. The stitches are removed, and heat, massage, and slight active movement can be started. By the end of the fourth week, considerable active movement on the part of the patient may be allowed without danger of refracture. Here again, contrast baths, various forms of heat applied daily, or every other day, massage, and frequent periods of active movement will hasten recovery and will prevent the prolonged swelling in the ankle and foot which practically always follows six weeks of immobilization in a cast.

FRACTURES INTO ANKLE JOINT

Fractures through the infra-articular face of the tibia and fractures through the articular surface of the astragalus are not uncommon but

These cases should be treated either by prolonged gradual mobilization of the joint by physical therapy methods or by a period of physical therapy followed by manipulation.

HEAT AND MASSAGE.—Heat is always indicated. It may be given as diathermy, hot fomentations, hot baths, and preferably, contrast baths or hot paraffin baths as advocated for the hand. Massage, first of the stroking and later of the kneading type, accompanied with a sense of stretching and freeing of adhesive bands, should be given daily.

EXERCISE.—Exercise, especially active movements by the patient himself, is most valuable. If there is no contraindication for active use of the foot, mechanical apparatus may be used to increase the amount of exercise. Pedaling a sewing machine or a jig saw is a good

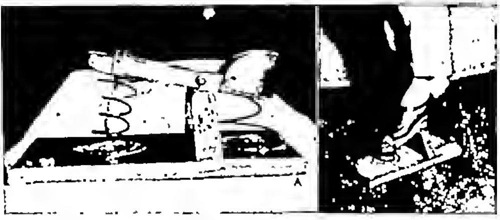

FIG. 34.—A, an ankle exerciser; B, same as Fig. 34, a.

occupational therapy maneuver. Figure 34 shows an ankle exerciser which has been very beneficial in overcoming stiff ankles due to fibrous ankylosis. Pedaling a bicycle is another excellent exercise. The bicycle can be made stationary by holding the rear wheel from the floor on a bracket. None of these exercises should be persisted in until the part is fatigued, and if swelling or reaction follows, the amount of exercise must be decreased.

FORCEFUL MANIPULATION.—Forceful manipulation of the stiff ankle joint under anesthesia is a questionable procedure, although the ankle joint will stand this better than most joints. Some advocate forceful correction, securing a certain amount of joint movement and then placing the ankle joint and the foot in a cast to hold this movement for a few weeks and then repeating the maneuver. Personally I am opposed to the cast immobilization, especially immediately after

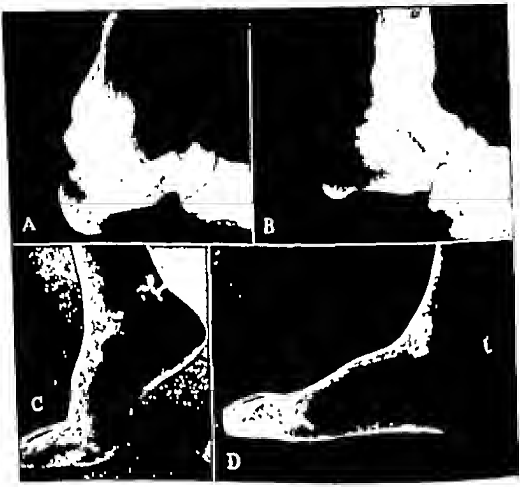

FIG. 33.—*A*, author's case of complete dislocation of the astragalus; *B*, same as Fig. 33, A, following operative replacement of the dislocated astragalus; *C*, illustrating the amount of function in the same case six weeks following the injury; *D*, same as Fig. 33, C.

follow. Seldom should immobilization of these fractures be permitted for more than two weeks without removal of the cast or fixation splint for the purpose of heat, contrast baths, massage, and ankle movement. The day of prolonged immobilization of the foot in a plaster cast followed by weeks devoted to overcoming the swollen edematous condition of the member and the pain and stiffness so common in foot injuries has passed. There will always be a certain number of these complications, but closer attention paid to physical therapy measures herein outlined will prevent the majority of them.

STIFF ANKLE JOINT DUE TO FIBROUS ANKYLOSIS

This is usually due to prolonged fixation following fractures in the lower extremity or to sepsis following either local trauma or a secondary infection. As a rule, the ankylosis is in a faulty position, and too often it is accompanied by a certain amount of footdrop.

BONY ANKYLOSIS OF THE ANKLE JOINT

If the weight-bearing angle and the position of the foot are practically normal, it is questionable whether an attempt should be made to overcome the stiffness. When the ankle joint, however, is ankylosed in a faulty position, operative procedure is necessary. Sometimes only a wedge of bone from the anterior portion of the ankle joint is removed to allow the foot to be brought to 90° of dorsiflexion. Sometimes the operation is for the removal of an obstructing piece of bone which has been displaced into the joint at the time of the fracture. Sometimes a refracture through the lower end of the tibia and fibula with a resetting operation to restore the weight-bearing angle is all that is necessary. In a few cases a typical arthroplasty of the ankle joint may be indicated.

Whatever the operative procedure, it should be followed routinely by heat, massage, and exercise in order to restore the greatest possible amount of function.

A cautionary note must be added concerning too early operations on the ankle joint, following a septic process. An infection at the site of a partial or complete arthroplasty can very easily spoil the result. Likewise, too early weight-bearing following an arthroplasty can start up an osteo-arthritis in this joint which will be disabling. Here, again, a prolonged period of traction is indicated following the operation. In many of these cases a walking caliper with traction from a shoe to the end of the caliper can be used. This will keep the joint surfaces separated and at the same time will give the healing advantages and function-restoring proclivities of the use of the leg and foot.

THE "CONGEALED FOOT"

Mention has already been made of the "congealed foot." The entire foot is swollen and firm. The skin is stretched, blanched, or cyanotic, is usually cold, and is often covered with a clammy sweat. The swelling usually includes the entire front portion of the foot from the astragalus to the toes. The patient complains of pain, and because of the pain he seldom bears any weight upon the extremity. He either uses crutches or hops. When visited in his home, he will be found going around the house resting the knee of the injured extremity upon a straight-back chair and moving this chair with him. I have recently seen a case of this nature of four years' standing. Several years ago I had such a case referred to me from Jefferson Barracks which had persisted for two years. A heavy object fell upon this patient's foot, fracturing two of the metatarsals. The foot was badly swollen from the time of the accident and this swelling, which was at first somewhat edematous and soft, gradually became firm but persisted the entire two years. I treated this foot for eight months without relieving the

manipulation under gas, because of the danger of swelling and traumatic reaction from the treatment.

After two weeks of a very active physical therapy régime, as outlined just above, more forceful manipulation of the ankle may be considered. These two weeks of prolonged physical therapy often show whether there is a tendency for recurrence of an old infection. A slight inflammatory reaction or even a cellulitis may develop around old scars. Certainly no manipulative procedure should be carried out in the presence of a potential infection. If there is no reaction after two weeks of strong massage and active exercise, and especially if the parts have been loosened up somewhat by this procedure, forceful manipulations, preferably without anesthesia, may be considered. The foot is grasped and strong traction is made downward from the ankle joint. Usually there is a certain amount of footdrop present. Gentle but increasingly strong flexion and extension of the ankle joint, working it back and forth, followed by strong lateral movements, are now carried out by the surgeon. The patient will usually complain of pain, but as a rule it is not severe. A sensation of stretching and sometimes of a sudden tear of an adhesion, followed by a more marked movement of the foot, frequently accompanies these maneuvers. Immediately following manipulation, heat, the whirlpool bath, or a local foot bath is used and the patient is instructed to keep moving his ankle to maintain the amount of movement gained. The heat, massage, and exercise are persisted in daily, and after a week a second forceful manipulation is carried out. Thus by alternating physical therapy and manipulation, function can be restored in the majority of cases of this nature.

Occasionally a tenotomy on the tendon Achilles is necessary. Sometimes a great deal of time and effort must be expended to overcome swelling in the foot, the poor circulatory condition of the foot, and the footdrop before the ankle condition can be manipulated. Occasionally the above manipulations must be carried out under anesthesia. When this is done, the Thomas wrench is usually used. The condition to be corrected is usually an equinus position of the foot with an extensive area of fibrous adhesions between the end of the tibia and the bones of the foot or between the fibula and the bones of the foot. Correction of this deformity by forceful manipulation with the Thomas wrench may require a certain amount of fixation of the foot in the corrected position to prevent recurrence. A metal aluminum splint or a plaster splint moulded to the back and opposite side of the foot, leaving the injured areas open for the application of heat and massage, is better than the application of a plaster cast. Within three days the immobilization splint can be removed for a treatment of heat, massage, and slight exercise, after which the splint is reapplied. The more frequent the periods of mobilization and exercise following forceful manipulation, the less danger there is of recurrence of the condition.

This treatment is persisted in for from two to three weeks. Occasionally the patient will bear weight upon his foot gingerly at the end of that time, but as a rule, weight-bearing will not be tolerated. However, improvement in the condition depends to a large extent upon redeveloping function. Two years ago Dr. Ralph Carothers, of Cincinnati, Ohio, suggested to me the use of a walking caliper in these old "congealed feet." Since then I have used it in two cases with what I consider excellent results.

Use of Walking Caliper.—A plaster cast is applied from the toes to just below the tibial tuberosity at the knee. In this cast is encased a walking caliper. The patient is then given a pair of crutches and taught to walk, bearing the weight of the injured leg upon the iron loop of the caliper projecting below the cast. After the patient has learned to walk with this caliper, he is allowed to go home and persist in this walking for four weeks. He then returns to the hospital or the physical therapy laboratory, when the caliper is removed and another séance of two to four weeks of heat, massage, and efforts at active exercise are carried on. Again the walking caliper is applied and the patient is allowed to return home for another period of four weeks. Usually, upon his return at the end of this period and following a period of massage and exercise, the patient can be persuaded to walk in a shoe, the leather of which has been cut so that it will fit his foot. If possible, he is persuaded to give up crutches and use canes. Continued use of the foot with continued contrast baths, massage, and exercise usually completes the cure of this condition. The treatment often must be persisted in for months.

Case IV.—Figure 35 shows a foot which was so badly crushed that amputation of three of the toes was necessary. The foot remained badly swollen and developed into the typical "congealed foot." The patient was referred to me from West Virginia. His local physician, according to the patient, had advised an amputation above the ankle. He had been treated by "every kind of light known," so he stated. He was finally pronounced a permanent total disability case. When he was referred to me, four years had elapsed from the time of his injury. At the first examination, the patient would not allow me to touch the stumps of the amputated toes. He wore padding inside his sock over the amputated stumps and wore no shoe. He was using crutches but walked around the office by hopping. The foot was swollen more than twice the size of the well foot. My first inclination was to advise an amputation of the leg at the site of election, viz., the junction of the lower and middle thirds of the tibia. Before recommending this, however, I placed the patient in the hospital and started the above treatment. At the end of two weeks I was able to massage lightly over the end of his stump and could massage the rest of the foot. The walking caliper was applied and he was allowed to return to his home. He used the walking caliper for six weeks before he reported again. The extra two weeks were added by the patient because he dreaded to give up the caliper. He remained in the hospital two and a half weeks for physical therapy, as

condition. Five years later I heard that this patient was still using crutches.

The prevention of this condition is to relieve the persistent swelling which frequently follows crushing injuries of the foot. The presence of a fracture should not explain the swelling and lull the surgeon to sleep over the condition. It is practically always due to hemorrhage over the dorsum of the foot and under the thick plantar fascia. If, within a short time, such a foot does not yield to the elevated position with the application of hot and cold fomentations and the use of the contrast bath, it is wiser to make several small incisions and evacuate the blood clot and the blood serum than to leave these in place to become organized, shut off the circulation, probably develop a low-grade cellulitis in the foot with a certain amount of endarteritis, and finally, the "congealed foot."

When such a case presents itself, the surgeon is immediately confronted with two problems: (1) how to overcome the pain in this foot so that the patient will tolerate a certain amount of massage and assisted active motion; as a rule, such a patient is very nervous; he is afraid to let the surgeon touch his foot, even for examination, and will jerk it away at the least attempt at massage; and (2) how to secure the great advantage of function and exercise to help overcome the condition—in other words, how to make the patient walk on this extremity. The habit of not using it for months and often years must be overcome.

Improvement of Circulation.—Such a patient should at first be treated in the hospital. The first efforts are directed toward improvement of the circulation. As described in similar conditions in the hand, the contrast bath is an excellent stimulation of circulation. The foot is immersed in a local foot bath with the temperature of the water from 100° to 110° F. (37.7° to 43.3° C.) or more if the patient can stand it. After 12 min. of this bath, the foot is immediately immersed in a second bath of cold water of approximately 40° F. (4.4° C.) for 3 min. This contrast bath is repeated three times, and given twice daily. The patient is then put to bed and the foot is elevated on pillows and encased in large, hot fomentations, the base of the fomentations being a saturated solution of magnesium sulphate. The fomentations are changed every two hours. For a period of one hour between each change of the fomentations, the foot is placed under an infra-red lamp or an electric baker. In the evening the contrast bath is repeated and the fomentations and light are kept up during the night. After three days of this treatment, light massage is started in the nature of stroking, beginning at the toes and extending up the foot and leg in the line of venous flow. The strength of this massage is increased as the patient can stand it. If the skin shows signs of becoming water-logged, the hot fomentations and contrast bath are replaced by the hot paraffin bath as described under Hand Injuries.

Functional Joint Conditions

This could make a chapter in itself, and therefore only a few of the conditions will be mentioned.

TRAUMATIC NEUROSIS

The more cases of trauma one sees, the less is his tendency to diagnose them as traumatic neuroses. Many of the latter have, as an underlying basis, a minute, often undiscoverable organic lesion which, if ferreted out, accounts for the apparent neurosis. A small adhesion within the knee joint may cause pain upon certain movements. Physical findings are practically negative and the x-ray is of no assistance. The patient, however, learns to avoid these sensations of pain by developing the habit of avoiding the given movement. A faulty function of the joint follows. The patient may visit many physicians who, failing to find an organic explanation of the condition, tell him there is nothing wrong and that it is only a nervous condition. The oftener he is told this, the more self-conscious he becomes, and the more he feels misunderstood. Naturally such a patient develops a certain amount of neurosis. Therefore, before classifying any patient as neurotic, careful search should be made for all possible organic explanations of the condition.

Many cases of joint injuries are treated by prolonged immobilization with disuse of the muscles, and nothing special is done to preserve muscle coördination and joint sense. As far as ordinary examination goes and as far as x-ray evidence shows, the trauma of the joint is "cured." However, the patient cannot or will not use the member. At examination the surgeon too often gives his sole attention to the patient's exaggerated efforts to use the member and to the neurologic findings of atypical areas of anesthesia and changes in the temperature sense. Most of us fail to grasp the fact that prolonged immobilization and disuse lower the sensitiveness of the sensory nerve endings and therefore may contribute to the neurologic signs frequently responsible for the diagnosis of neurosis. Finally, seeds of phobia are often planted in a patient's mind by the physician, the relatives, or by some interested lawyer, and these fears, combined with the long disuse of the muscles and joints, may be the underlying cause of his neurosis. I am quite sure that in the above-described case of "congealed foot," the removal of fear of amputation and of permanent disability and the encouragement given to this patient during the period of his treatment decreased considerably the symptoms of neurosis which were discovered in his case during his first two weeks in the hospital. For example, this patient had atypical areas of anesthesia over his foot and lower extremity. These areas of anesthesia were variable, that is, they were present in one area at one examination and at the second examination were absent over that area but present over another. He

above outlined. During this period he went to the occupational therapy department and pedaled the jig saw. Instead of replacing the walking caliper, he consented to use an old shoe which was cut to make it very loose. With the aid of crutches he walked with the shoe, bearing very little weight upon the foot. He was allowed to return home for another month and is now back in Chicago, receiving further physical therapy. He has a new pair of shoes of the blucher type. The top of the shoe at the base of the tongue was cut and a piece of leather approximately two inches wide was sutured in to make the shoe large enough to accommodate his foot. He is

FIG. 35.—Walking caliper in case of congealed foot.

walking with the aid of two canes. After two weeks of further physical therapy, he reported to my office with practically no swelling in the foot. He had had a shoemaker remove the piece of leather inserted in the top of the new shoe, thus restoring the shoe to normal, showing that the swelling had disappeared. That day he had walked six miles, using his canes only for assistance. He informed me that he intended to walk back to his hotel after leaving my office—a distance of a mile and a quarter. This patient is almost cured, but treatment will continue until he has discarded his canes. I believe he will be able to return to light work in another two months.

immediately the wrist flew into its stiff position and the fingers became extended and rigid. I immediately ordered the patient up for a second anesthetic but he refused to go. I then told him that I would try to reduce the condition under local anesthesia. A rather large, dull needle was used and salt solution was injected on the dorsum of the wrist and hand. This was done none too gently and the patient complained bitterly. I told him that the injection must be made several times until we began to notice movement in his wrist and fingers. Injections were repeated and attempts made to move these parts. Finally, a little motion was gained and was gradually increased until again we had the wrist dorsiflexed and the fingers completely flexed. They were again bandaged in this position. Three days later the bandages were removed, and although some stiffness returned, we were able to secure considerable movement in the wrist and fingers. Again they were bandaged in the flexed positions. Two days later the bandages were left off and massage and joint reëducation exercises were started. The patient was told to make pulp balls and each day he was to give me from 12 to 20 pulp balls on my return visit. Within two weeks the condition was cured. In my judgment this was a true case of traumatic hysteria.

Case VI.—A second patient was recently referred to me with a stiff knee joint. He had been operated on some eight months previously for a dislocated internal semilunar cartilage. Following this operation, a plaster splint was applied to the posterior aspect of his leg and thigh and was left in place for six weeks before it was removed. Many attempts had been made to secure movement in the knee, but without result. The patient walked stiff-legged with a rather exaggerated limp and complained of pain in the knee. I kept this patient at the hospital and started physical therapy in the form of heat, massage, electric stimulation of the muscles, and assisted active exercises. Within two weeks the patient had developed a 45° flexion of his knee. Progress seemed stationary at this point. Under general anesthesia I was able to secure 90° of flexion of the knee joint without any trouble. The knee was bound in this position and the patient allowed to awake. He complained of some pain and discomfort but seemed happy over the amount of flexion obtained. While he was under the anesthetic, further flexion seemed limited. This limitation of motion gave the sense of fibrous limitation rather than of bony obstruction. Undoubtedly a certain amount of contraction of the capsule and ligaments and foreshortening of the weaker flexor group of muscles accounted for this limitation of flexion. Further physical therapy was given and we were always able to secure the 90° flexion of the knee. Further flexion was gradually returning. It was my opinion that this patient would make better progress at work rather than by continuing physical therapy treatments, therefore he was discharged.

Two things had happened to account for this patient's neurosis: Right after the operation the doctor had told him that he had cut one of the ligaments and that the sewing up of this ligament had shortened it so that the patient must not expect to have full range of motion in the knee joint. The surgeon who performed the operation lived in another town. When he saw the patient at the end of six weeks with the posterior splint still in place, he criticized the local doctor in the presence of the patient, stating that the splint left on so long was liable to make a stiff knee. In my opinion these two things contributed to the neurosis. After returning home, this patient refused to go to work until a settlement was made for his knee

made exaggerated efforts to swing his lower leg when first examined, and, as one of my assistants expressed it, "If his foot wasn't so swollen, I would call him a neuro." All these signs and symptoms have disappeared with the improvement of the condition of the foot.

A pure traumatic neurosis in a joint usually gives the picture of a stiff joint. Occasionally it is a flaccid condition of the joint. The history of injury is often very slight. When the condition of marked stiffness develops immediately after a slight injury, I am more suspicious of its being a neurosis than when it develops several days or weeks after the injury. In the latter I am suspicious of adhesions or of other causes of painful joint which hold it rigid. Frequently the hysterical stiff joint has only the manifestation of stiffness and there is no complaint of pain. If the condition is seen early, there is no swelling. If areas of anesthesia are found about the joint early, I am more suspicious of their being due to a functional condition than when they are seen late and after long disuse of the muscles. In the latter instance the condition may be due to lowered sensitiveness in the sensory endings.

Examination under anesthesia is one of the best means of differentiating between the functional stiff joint and the stiff joint due to some obscure internal derangement.

CASE V.—This patient was referred to me for a stiff wrist joint. The condition followed immediately after a falling rock hit the back of the patient's wrist during a blasting in a quarry. His physician stated that the wrist was never swollen but that the patient complained from the start of severe pain. The wrist was held perfectly straight and rigid with the fingers rigidly extended. The patient would not tolerate manipulation because of alleged pain. He was seen by me some three months following the injury. By this time the rigid position of the wrist and hand had caused a certain amount of slight swelling and cyanosis in the extremity. (Try holding your own hand rigid in an awkward position for 30 min. and note this tendency to swelling and cyanosis.) Physical examinations were negative except for the rigidity and alleged pain over the back of the wrist and hand. The entire dorsum of the hand showed anesthesia to pin prick. X-ray examination was negative. The condition persisted even when the patient was asleep. It was explained to the patient that a diagnosis could not be made without an anesthetic.

Under rather deep anesthesia I was able to flex and extend the wrist without any evidence of resistance as from adhesions or bony obstruction. The fingers could likewise be flexed and extended. The wrist was placed in dorsiflexion, the fingers completely flexed, and the thumb abducted, and then the entire hand and wrist were firmly bandaged in this position. The patient was allowed to awake from his anesthesia and was returned to bed. When he became sufficiently awake to realize the position of his hand and wrist, he cried bitterly and complained of pain. Sympathy without censure was given to him. Sedatives were administered, and after he awoke from them his complaints of pain were less violent. The next day the bandages were removed for the purpose of exercising the wrist and fingers. Almost

immediately the wrist flew into its stiff position and the fingers became extended and rigid. I immediately ordered the patient up for a second anesthetic but he refused to go. I then told him that I would try to reduce the condition under local anesthesia. A rather large, dull needle was used and salt solution was injected on the dorsum of the wrist and hand. This was done none too gently and the patient complained bitterly. I told him that the injection must be made several times until we began to notice movement in his wrist and fingers. Injections were repeated and attempts made to move these parts. Finally, a little motion was gained and was gradually increased until again we had the wrist dorsiflexed and the fingers completely flexed. They were again bandaged in this position. Three days later the bandages were removed, and although some stiffness returned, we were able to secure considerable movement in the wrist and fingers. Again they were bandaged in the flexed positions. Two days later the bandages were left off and massage and joint reëducation exercises were started. The patient was told to make pulp balls and each day he was to give me from 12 to 20 pulp balls on my return visit. Within two weeks the condition was cured. In my judgment this was a true case of traumatic hysteria.

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disability; thus the possibility of a compensation neurosis was injected into the case.

COMPENSATION NEUROSIS

Often this desire for settlement, in public or industrial accidents, furnishes the basis for the neurosis. The term "compensation neurosis" best explains this condition. However, surgeons must be careful not to make this diagnosis until they have ruled out all possible organic lesions and all pure neuroses which may be the true cause. The tendency to pin "compensation neurosis" upon these injury cases is becoming more prevalent than the often-made diagnosis of malingering.

MALINGERING

True malingering is a rare condition. Most cases must be placed under careful observation in the hospital before this diagnosis can be definitely proved. When the nurses, internes, or orderlies discover that a patient with an alleged stiff joint is using that joint in the bathroom or while playing a game of cards with the other patients in the ward and that it again becomes stiff as soon as the surgeon comes to the ward, one can definitely diagnose malingering.

Many cases, physically and mentally weakened by prolonged suffering, develop neuroses. Gradually they come to realize that they can use the given joint, but the habit of loafing and of depending upon others, and the dread of again assuming the burdens of life cause them consciously to hold fast to their complaints and add other signs and symptoms to the condition. Often the question of settlement is involved. These are the cases of traumatic hysteromalingering that are far more common than pure malingering.

In functional conditions of the joint one must avoid getting into a rut of treatment. I have had physicians say to me: "Here is a case of traumatic hysteria. I have told him there is nothing wrong with him, but we keep him satisfied by giving him a light treatment two or three times a week." What a poor treatment for neurosis! On the one hand, his physician tells him there is nothing wrong with him, while on the other hand, he has him reporting for treatment. No wonder his neurosis is at a standstill or grows worse.

The use of physical therapy as a means of "suggestive treatment" or for its "psychologic effect" is a very questionable form of therapy. It is easy to stimulate ideas of grandeur and enhance the seriousness of the case in the patient's mind with physical therapy when a functional condition is the underlying cause of his disability. You can sometimes rub in more neurosis in an hour than you can rub out in a year.

FORMS OF PHYSICAL THERAPY

This chapter has been written for the average surgeon who must depend upon the intelligent use of his hands and the common-sense use of the ordinary physical therapy apparatus usually available for the treatment of his cases.

Machines.—Diathermy machines, expensive quartz lights, various kinds of electrical apparatus, and other more or less complicated forms of machine therapy should be provided by a physician in your community who is specializing in physical therapy. Every hospital should have a thoroughly equipped physical therapy department supervised by a physician familiar with the use of these more expensive and more complicated types of physical apparatus. The surgeon should be able to refer his cases to such a department for intelligent, common-sense physical therapy treatment. On the other hand, the surgeon should not lose interest in his case when it is referred for such treatment. It is only by close coöperation and coördination of effort between the physical therapy department and the surgeon that the best results in functional restoration can be secured.

Occupational Therapy.—Occupational therapy should be made a definite part of, or should be coördinated with, the physical therapy department. There is an increasing number of well-trained physical and occupational therapy technicians who can be placed in these departments. To leave the physical therapy and occupational therapy to the technicians, unsupervised by a physician especially qualified in physical therapy, or, if this is impossible, unsupervised by the surgeons in the hospital interested in securing functional restoration, is a mistake. The departments will grow and increase in usefulness just as the interest of the staff in these departments grows. The technicians realize this fact and are most anxious to have their work supervised.

Importance of Physical Therapy.—When physicians and surgeons realize that physical therapy definitely belongs to the medical and surgical field, they will cease sending these cases for unsupervised treatment to laymen who are developing so-called physical therapy offices in almost every city. Masseuses, gymnasts, health institutes, osteopaths, and others who are treating all comers by their various methods of massage, manipulation, and exercise instead of working in close coöperation with the physicians who know the needs of their patients, belong in the class of cultists.

In this chapter on joint injuries, I have gone into considerable detail concerning the physical therapy measures employed for each individual joint. The surgeon must realize that the problem is more complicated in many of these cases than the mere heating, massaging, and exercising of the given joint. The joint is a component part of the extremity. The injury itself or the prolonged disuse of muscles,

nerves, tendons, and ligaments in the remaining portion of the extremity may account for the loss of function. No matter how much attention is given to restoration of function in one joint, our efforts may be nullified if we fail to treat the joints, muscles, nerves, and other soft tissues in the rest of the extremity.

Coördination of the muscles and redevelopment of joint sense are essential in restoring joint function. Thus, in injuries of the lower extremity, the entire attention must not be directed to the stiffened knee. The patient must be taught how to swing his entire leg, how to abduct and adduct the leg, how to flex and extend his foot, how to walk in a straight line, climb stairs, and climb over objects, how to stand on his tiptoes, and similar exercises, all directed to reëstablishing muscle coördination.

Influences such as gravity and other conditions responsible for the assuming of faulty positions in an extremity must be constantly guarded against by the use of proper splints, traction, and corrective exercises. Often the strong group of muscles so dominate the function in the leg that the weaker antagonists cannot act. This is seen in injuries of the shoulder joint when the strong pectoralis major and the latissimus dorsi muscles have become overcontracted during a period of arm adduction fixation. Here gravity plays a part in further weakening the abductors. Therefore, during the treatment of the upper extremity injuries, attention must be given to maintaining function in the weaker muscles, to developing coördination between the abductors and adductors, and to protecting the part against gravity. The wristdrop and the footdrop are other excellent examples of the deforming effect of gravity.

Coöperation of Patient.—Finally, *the patient cures himself*. In all cases of old joint dysfunction and deformity the ultimate restoration of function depends chiefly upon the patient. The surgeon builds the proper foundation for restoration and then becomes the guide and teacher, but the patient must put forth the effort and stick-to-it-iveness that results in the cure. Both the surgeon and the technician must constantly impress this fact upon the patient. Unless you can secure his coöperation and unless he puts forth great efforts to show a slight daily or weekly improvement in his condition, physical therapy will be of no avail.

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CHAPTER FOUR

PHYSICAL THERAPY IN BONE AND JOINT TUBERCULOSIS

WILLIS C. CAMPBELL, M.D.

The occurrence of tuberculosis in bones and joints is but an incident in the dissemination of a constitutional disease; orthopedic treatment alone is consequently ineffectual and every effort must be employed to eradicate the systemic infection. The aim of antituberculosis therapy is to utilize to the highest degree the body's reparative powers by means of rest, a high caloric diet, drugs, tuberculin, fresh air and sunlight. Orthopedic treatment, whether nonoperative or surgical, consists of measures which prevent deformity and immobilize the affected articulation until the tuberculous process has been arrested by natural forces. The local and constitutional treatment cannot be dissociated except for convenience in description, but since light therapy has such a definite action on the tuberculous process, it should be employed routinely in every case of bone and joint tuberculosis.

Etiology.—The infectious nature of tuberculosis had been suspected for many centuries, but it was not until 1882 that Koch succeeded in isolating and cultivating the tubercle bacillus. Several types of tubercle bacilli are recognized, but only two types, the human and the bovine, commonly cause infection in the human body. The bovine type of infection is more prevalent in children than in adults, the incidence of the bovine type constituting nearly one-third of the total number of cases in very young infants. When all ages are considered, the incidence of bovine tuberculosis amounts to only one-fourth of the total number of cases. There is no essential difference in the pathologic reaction produced by the two organisms, so that for practical purposes, differentiation of them may be disregarded. The portal of entry in either case is through the mucous membranes of the alimentary canal or respiratory system. The invasion of these tissues is followed by tuberculosis of the lymphatic nodes, cervical or mesenteric, and from this focus, the bacilli are distributed through the blood stream to the bones or joints.

In addition to the infecting organism, two other causative factors should be considered; first, the predisposition of the patient, and secondly, the local conditions that favor the implantation and growth of the bacillus. Hereditary transmission has been disproved, but direct infection from association with a tuberculous member of the family

is of frequent occurrence. Mild trauma is an accepted predisposing cause, while severe trauma, as extensive fractures or crushing of the joint surfaces, is rarely, if ever, followed by tuberculosis. Bone and joint tuberculosis is essentially a disease of childhood, beginning more often between the ages of three and five, but it is undoubtedly more common in adults than is generally known, as many cases of chronic arthritis continue until death ensues from other causes without a correct diagnosis having been made. Joint tuberculosis is usually a monarticular affection. The spinal column is affected most often, next in frequency being, respectively, the hip, knee, and ankle joints; the joints of the upper extremity are less often invaded.

Pathology.—The tubercle bacillus causes inflammatory changes which are so characteristic that a diagnosis may be made by histologic examination, even without the finding of the bacillus. The histopathology of tuberculosis in a joint is the same as that of a tuberculous process elsewhere in the body. Following the deposition of the tubercle bacilli in the tissues there is a proliferation of the cells lying in direct contact with the bacteria which results in the formation of a tubercle. The microscopic examination in the early stage shows an accumulation of endothelial leukocytes and surrounding this, an area of lymphocytes. Later, the endothelial leukocytes in the center of the tubercle coalesce and form a giant cell of the foreign body type. At this stage, the giant cell is surrounded by a zone of amorphous glandular material. Encircling this, and encroaching upon it, is another zone composed of endothelial leukocytes, many of which show a radial arrangement of their nuclei. Finally, there is an invasion by lymphocytes, polymorphonuclear leukocytes, and fibroblasts. As the lesion becomes older, the fibroblasts are found nearer the center of the tubercle. The blood vessels become occluded, resulting in necrosis, and the toxins which are elaborated by the bacilli may also produce disintegration and caseation.

The pathologic process usually begins in the bone, just external to the epiphysis, in the vascular area known as the metaphysis, although primary tuberculosis of the synovial membrane is occasionally observed. There is a gradual atrophic and destructive process which invades the joint from without, the articular surfaces being undermined. Coincidently with invasion of the bone, there is a sympathetic arthritis, and after the joint is invaded, there is a gradual proliferation of the synovia, hypertrophy of the villi, formation of granulation tissue in profusion, and erosion of the articular surfaces. There may be a change in relation of the joint, with malposition, subluxation or complete dislocation. Cold abscesses are formed from caseation and necrosis; they follow the line of least resistance and appear beneath the skin as fluctuating masses. The evolution of the process requires from one to three years, depending upon the joint involved, the resistance of the individual, and the virulence of the infection.

Symptomatology.—The chief symptoms of joint tuberculosis are pain, disability, limp, swelling, stiffness and night cries. The physical findings are swelling of the joint, with or without apparent increase of the synovial fluid, muscular atrophy on either side of the joint, increased local temperature and daily elevation of the general body temperature. The onset is gradual and insidious; spontaneous pain and pain on attempted motion are early symptoms. The pain is referred to a more distant point in the extremity when the disease is in the proximal joints, as the hip and shoulder; when the disease is in the peripheral joints, the pain is local. Swelling is more apparent in the superficial joints and the local heat is usually increased. Muscular atrophy occurs earlier and progresses more rapidly than in other joint affections. Muscular spasm, or rigidity, is a characteristic manifestation. Local symptoms are more definite in children than in adults.

The muscular spasm limiting joint motion is less pronounced in adults and years may elapse before there is any material impairment of function. This is due to the fact that the bones of adults are harder, more dense and not so easily invaded as the bones of children. In the acute stage, deformity may be caused by muscular spasm, but in the later stages the malposition may be attributed to muscular and ligamentous shortening, to bony destruction or to ankylosis in a faulty position.

At the onset the patient is usually well nourished, and there may be no debility until the symptoms become acute, with excessive pain and loss of sleep. Loss of weight is rarely observed until the late stage or as the result of some complication, such as secondary infection. The temperature at the onset may be moderately elevated; in tuberculosis of the hip or spine, the afternoon temperature seldom exceeds 37.2° to 37.7° C. (99° to 100° F.), but when the knee, ankle or elbow is involved, the temperature is usually elevated to 38.3° to 38.8° C. (101° to 102° F.). Constitutional symptoms are more apparent in children than in adults. In adults, fever is much lower than in children; moreover, in adults the disease may continue indefinitely without elevation of temperature unless complicated by secondary infection.

The most frequent complications are tuberculous abscess, pulmonary tuberculosis, tuberculous meningitis and secondary infection with pyogenic organisms. Abscesses, when deep, may be evidenced by a slight increase in temperature and may cause symptoms by mechanical pressure according to their location. Secondary infection is the most common late complication, being the cause of high temperature, night sweats, excessive loss of weight, and often death by the synergetic action of pyogenic bacteria and the *Bacillus tuberculosis*. Amyloid degeneration of the liver, spleen and other viscera is a sequence of prolonged sepsis.

Diagnosis.—The characteristics of tuberculous joint disease are chronicity and bone destruction with but slight tendency to new bone formation. The diagnosis can often, but not always, be made by the symptoms and physical examination. There are no abnormal changes in the blood which are of diagnostic value, except that a high cell count differentiates or indicates a secondary pyogenic infection. The von Pirquet skin test is of value in children under twelve years of age, and is of greater significance when negative than when positive, as a large percentage of apparently normal persons give a positive reaction. The

Fig. 1—Roentgenogram showing tuberculosis of wrist. Anteroposterior view. Note osteoporosis of the osseous structure and destruction of the articular surfaces of the radius and carpal bones.

Fig. 2—Same as Fig. 1. Lateral view.

joint fluid or material from a cold abscess may be aspirated and submitted to the laboratory for examination, but the tubercle bacilli are not often easily demonstrated in the fluid. Injection of the aspirated material into guinea-pigs may be made to confirm the diagnosis; at the end of six weeks the guinea-pig is killed and an autopsy made to reveal any evidence of tuberculosis. This test is seldom of value in the early stage, as the organism is rarely present in the fluid until destruction begins. The test is also accurate only in proportion to the proficiency of the examining pathologist. Biopsy

is becoming more popular as a diagnostic measure and may be employed with impunity in all superficial joints, such as the knee and ankle, but in the light of our present knowledge, it is certainly not practical in such locations as the hip and spine.

FIG. 3—Spinal brace extending from occiput to knees for tuberculosis of the spine in a young child.

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FIG. 3—Spinal brace extending from occiput to knees for tuberculosis of the spine in a young child.

ROENTGENOSCOPY.—In the earlier stages the roentgenogram is generally negative and is of but slight diagnostic value until there has been definite invasion of the bone. The first signs noted are paleness of the osseous structure and distention of the capsule of the joint. After several months, destructive changes may be observed beneath the articular surface which is undermined. Erosion of the surface is observed only after extensive invasion of the joint, and, as the process advances, all parts of the joint will be destroyed. In the spine, the roentgenologic demonstration of paravertebral abscess may be the first positive evidence of tuberculosis, preceding any visible change in the vertebrae, although the abscess may be unrecognized in many cases. The abscess appears as a spindle-shaped mass, symmetrical and bilateral, surrounding the affected area of the spine. Paravertebral abscesses occur commonly in tuberculosis of the dorsal vertebrae; the frequency is considerably less in the other portions of the spine. The finding of an abscess, however, is important in establishing definitely a diagnosis of spinal tuberculosis, in determining the limits of the disease, and in evaluating the progress and prognosis of the particular case.

Little or no new bone formation takes place during the repair of tuberculous joints. With subsidence of the disease there is a gradual condensation of bone in the area involved and a restoration to normal osseous structure in the bone surrounding this area. After the process has entirely subsided, the bone will be increased in density as compared to normal bone, but the contrast is never so marked as in joints which have been infected with pyogenic organisms. When sinuses and secondary infection are complications, new bone formation may be observed. Healing without infection by the production of osseous tissue is more prevalent in tuberculosis of the vertebrae than in involvement of other joints.

Nonoperative Treatment.—The importance of instituting treatment as early as possible and of enforcing the necessary procedures consistently must be emphasized. Tuberculosis is an evolutionary process that runs an indefinite course; the length of time required for such evolution varies considerably, but all cases should be under close observation for a period of at least three years. The treatment consists of local measures and constitutional therapy, applied simultaneously and continuously until the disease process is arrested and encapsulated.

IMMOBILIZATION AND TRACTION.—Prevention of deformity may be considered to be the keynote of orthopedic treatment. Immobilization by apparatus allays muscular spasm and relieves pain. Traction may also be applied to separate the inflamed joint surfaces. Apparatus must be employed for a long period of time; it must maintain the joint in the most useful position for future function and should be so designed that it can be easily removed for heliotherapy or other light treat-

ment or, if not removable, will not prevent the light rays from reaching the entire surface of the body. When ambulation is possible, the apparatus should be constructed so as to prevent motion and the pressure from weight-bearing on the diseased joint. These measures must be strictly and continuously employed in conjunction with any and all forms of treatment for tuberculosis of joints, whether constitutional or operative. In those observed in the early stage, or even in a later stage before the deformity has been fixed by strong adhesions, malposition can often be corrected by special apparatus which, by well directed force, often combined with traction, very gradually and slowly aligns the affected part in the most useful position.

Care must be exercised at all times not to induce force too rapidly. *Brisement forcé*, or forcible movement either with or without anesthesia, must be employed with great caution in the treatment of tuberculous joints. Unfortunately this procedure is used very commonly, but such practice is capable of producing serious damage. Fibrous adhesions are more resistant than bony structures and therefore crushing of the atrophic extremities of the bones, gross fractures, and violent reaction within the joint, followed by further organization and stronger adhesions, may result. An even more serious contraindication is the probability of reactivating the local process, causing further dissemination of the disease and resulting in disastrous complications, such as tuberculous meningitis, which is always fatal.

The Ankle.—Conservative treatment with heliotherapy may be employed successfully in children with tuberculosis of the ankle, but it is rarely practical in adults on account of the length of time required to effect results. In all affections of the foot, apparatus must be employed to maintain the foot at a right angle to the leg. This may be accomplished by a plaster of paris cast extending from the upper third of the leg to the tips of the toes. From involuntary contraction of the tendo achillis and the force of gravity there is a constant tendency for the foot to fall into the position of equinus. A common error is made by applying a cast with the foot in this position, thus causing a serious complication by inducing fixed contracture of the tendo achillis. The cast may be bivalved so that either half may be removed without disturbing the position of the extremity when heliotherapy or other light treatment is given. Splints may be made of plaster of paris, celluloid, aluminum, steel or other material and when walking, a brace is necessary to relieve the foot from the pressure of weight-bearing.

The Knee.—Orthopedic measures of fixation and traction are applied to secure and maintain the knee in extension until the disease has become arrested; this requires from two to three years of continuous heliotherapy and other antituberculosis measures carefully administered. Partial immobilization, correction of mild contractures and relief of pain from muscular spasm are often accomplished by traction

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the spine. A plaster of paris cast or a plaster bed may be made which conforms closely to the contour of the back from the head to the tip of the sacrum. In young children, ambulatory apparatus should extend from the occiput to the knees. In older children and adults, ambulatory apparatus does not need to be so extensive. The Taylor spinal brace is sufficient for all lesions in the dorsal and lumbar spine below the level of the eighth dorsal vertebra. When the disease process is above the sixth dorsal vertebra, a head support must be attached to the spinal brace.

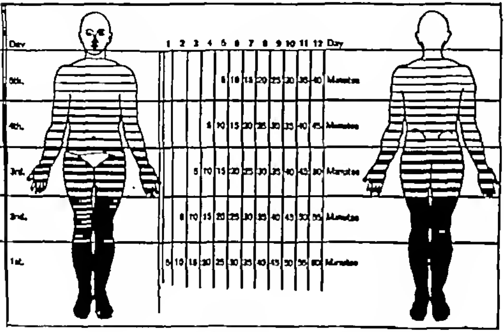

FIG. 4—Diagram to show the increase of exposure first twelve days.

The Shoulder.—Tuberculosis of the joints of the upper extremity is rare, especially in children, and the treatment is generally conservative. The joints should be immobilized in the position most useful for function. The most serviceable position for the shoulder is about 140 degrees' flexion, slight internal rotation and 135 degrees' abduction. This position can be secured by a plaster of paris cast applied to the extremity and body and extending to the iliac crests so as to obtain firm support. The elbow and wrist are usually immobilized as well, but the cast should not extend beyond the metacarpophalangeal joints in order to permit free motion of the fingers. The cast may be bivalved for heliotherapy. The position may be maintained also by a metal splint or a leather corset which includes the arm, forearm, shoulder and thorax.

which is secured by a weight and pulley—the well-known Buck's extension. The extension at all times must be in a direct line with the leg; when deformity is present, the pull should be begun in the angle of deformity and the apparatus adjusted as the deformity is corrected. The most efficient means of immobilizing the knee is a plaster cast which should extend from above the iliac crest to the toes. Splints of various types may be employed, the most satisfactory of which is the Thomas knee splint. This appliance with minor modifications may be used for the purpose of fixation and fixed traction during recumbency; for fixation as an ambulatory splint; and for ambulation with stilting and partial weight bearing by attaching the lateral bars to the shoe by means of a steel stirrup or, preferably, a caliper joint. Apparatus must not be discarded until the roentgenogram demonstrates complete organization of the osseous union, during which time physical therapy should be employed routinely.

The Hip.—If efficient orthopedic measures are instituted early and maintained throughout the active stage, the destructive process is restricted. The hip should be maintained in the most useful position for future function. Traction by Buck's extension may be instituted, the traction force being applied in the position of deformity and adjusted as the malposition is reduced. Apparatus to immobilize the hip must extend from the nipple line to the toes on the affected side and in most instances the opposite thigh must also be included. Fixation may be secured by a bivalved plaster of paris cast, or some modification of the Thomas hip splint. The caliper brace is employed frequently as a convalescent measure in affections of the hip joint, to prevent weight bearing.

The Spine.—Immobilization of each region of the spine presents a different mechanical problem. However, certain principles applicable to the entire spine will be considered with such variations as are required in the separate regions. The spine should be maintained in hyperextension, as pathologic processes in all regions more frequently invade the bodies of the vertebrae; when there is loss in continuity of bone in the vertebral body, there is a tendency toward flexion of the spine by gravity or muscular pull, resulting in kyphosis. In affections of the upper third of the spine, the weight of the head is an important factor, and apparatus for the purpose of fixation must also relieve or support the superincumbent weight of the head. In the lower lumbar spine, fixation cannot always be secured without including one or both hips.

When the process is acute, recumbency with spinal fixation is necessary and must sometimes be continued for one or two years. For this purpose, the patient is placed upon a Bradford frame, and traction to the head is applied to overcome muscle spasm when the cervical or upper dorsal regions are affected; traction to the legs is applied when the lower dorsal or lumbar regions are involved. The frame may be curved at the level of the disease process to enforce hyperextension of

on windows to protect smallpox patients against pitting was revived by Niels Finsen in 1893. The study of this problem led indirectly to the use of light for treating lupus, rodent ulcer and tuberculosis, and resulted in the founding of the Finsen Light Institute at Copenhagen.

In 1902, Bernhard noticed that meat exposed to sunlight at high altitudes did not putrefy. This observation led to the resumption of the treatment of surgical wounds with sunlight. The following year (1903) Rollier opened the Sun Cure Institute at Leysin, Switzerland and placed heliotherapy upon a systematic and scientific basis.

The energy which is emitted from the sun consists of a series of frequencies which are measured in hypothetical wavelengths in terms of units of the metric system. The rays travel in straight lines at constant speed but they vary in wavelengths. The shortest visible rays are the blue and violet and beyond them are the shorter invisible ultraviolet rays or chemical rays. Beyond these again are the still shorter roentgen rays and the gamma rays of radium. The shortest and the most recently discovered are the cosmic rays, supposedly generated by the synthesis of helium from hydrogen. The longest rays that are visible are the red rays, beyond which are the longer invisible infrared rays or heat waves which comprise radiant heat. The longest known group of rays are the hertzian or electric rays which measure up to one thousand feet in length and which are used at the present time primarily as carriers in wireless telegraphy. Sunlight acts on the organs of sight and has the three properties of heat production, light production and chemical action. All wavelengths appear to possess some light and heat properties and the ability to influence chemical reactions. As a rule, however, heat production is chiefly associated with the infra-red and red rays. The visible rays from red to violet differ from the rest chiefly by reason of their visibility, while the most active rays chemically are the ultraviolet.

Rollier regards the ultraviolet or actinic rays as the curative agent in tuberculosis and calls attention to the fact that all parts of the spectrum (red, orange, yellow, green, blue, indigo and violet), as well as the invisible rays, are more intense at high altitudes, and that seasonal variations in the width of the spectrum are not so marked as in low lands. Such variations, he thinks, are due to the formation of ammonia and nitrous compounds in the atmosphere from electrical phenomena, especially in the warmer months. The invisible rays are contracted and the effects of the solar treatment are thus decreased in summer; in winter there are few sunny days in the low countries, and the cold damp atmosphere, with excessive wind currents, does not permit general exposure. On the other hand, at high altitudes there is less seasonal variation in the spectrum, there are more sunny days, and the air is pure, still, and dry, permitting almost continuous insolation. Other authorities have demonstrated that equally satisfactory results can be obtained at any level, and in many portions of America heliotherapy can be given for at least nine months of the year.

The Elbow.—The most serviceable position for an elbow is that which places the forearm at slightly less than a right angle to the arm, with the forearm in supination or in the midposition between supination and pronation. A plaster cast for immobilizing the elbow in this position should extend from the metacarpophalangeal joints to as high in the axilla as is possible or consistent with the comfort of the patient. The cast may be bivalved or the posterior half may be used as a splint.

Splints conforming to the anterior or posterior surfaces of the extremity may be employed, but the posterior splint is more efficient and comfortable. This apparatus consists of an arm and forearm piece conforming to the posterior surfaces of the hand, forearm and arm from the metacarpophalangeal joints to a point on the arm at a level with the posterior axillary fold. As the forearm normally is in the position of about 15 degrees' valgus as related to the arm, the forearm piece on the splint must be joined to the arm piece at a corresponding angle.

The Wrist.—The most serviceable position for the wrist joint is extension or dorsiflexion, for in affections of this joint there is an ever present tendency toward palmar flexion and luxation. Plaster casts may be employed to prevent this deformity, or a simple splint made of sheet metal, called the cock-up splint, may also be used. This splint should extend from the middle of the palm to the upper third of the forearm. A notch should be cut over the palm to allow for the adducted position of the thumb and the thenar eminence. At the wrist joint the splint is bent backward or cocked up, to hold the hand in the desired degree of dorsiflexion or extension.

Heliotherapy.—The beneficial effects of the sun's rays upon disease processes have been recognized since ancient times; the first person on record to employ radiation in treatment was John Gadsden who treated smallpox patients, in the thirteenth century, with red light to prevent scarring. The treatment of ulcers by sunlight was undertaken by Faure in 1774 and of wounds and inflammations by Le Peyre and Le Comte in 1776. The application of this method of treatment to tuberculosis was probably first made on a rational scale by Bonnet of Lyons in 1845. This practice seems to have been discontinued soon afterward, but the physical basis of light and its chemical and biologic actions continued to be the subject of investigation of numerous scientists. Charcot, in 1859, showed that the effect of sunlight on the skin was not dependent upon the heat rays and, therefore, must be due to the ultraviolet rays. In 1877, Downes and Blunt published the results of experiments in which a beam of light was dispersed with a prism and the various portions were allowed to fall on plated cultures of bacteria, proving that light retards the growth of bacteria and, furthermore, that the shortest exposures necessary are in the ultraviolet region. The use of red shades

circulation. The appetite is improved and the digestive functions are more normal. The metabolism is also accelerated, although this is probably due not to light action alone but to the coincident exposure to fresh outdoor air. It has been shown that the blood platelets, if low in number, may at times be markedly increased by ultraviolet radiation; the lymphocytes may also be increased. The erythrocytes and hemoglobin are probably not increased by light alone, altitude playing an important rôle in their production. Increase in the red cells and hemoglobin, however, has been observed constantly in patients treated by heliotherapy at Memphis, Tenn., where the elevation is approximately 300 feet above sea level.

Technic.—Heliotherapy can be given to better advantage in institutions especially equipped for the purpose. When this is not practical, instruction for several weeks in an institution will be of material advantage before treatment is begun at home, which can then be carried out very effectively. A place which is protected from wind currents should be selected for the treatment. A southern exposure is preferable so that both morning and afternoon sunlight can be secured. The location must be open above to the sunlight and not enclosed by glass, metal or wire screening. A cot or bed upon which the patient may lie should be provided. All clothing is removed, the head is covered by a broad-brimmed hat and the eyes are protected from the glare of the sun by a pair of amber glasses. A sheet may be used during the first week to drape the unexposed portions of the body. After tolerance to the sun has been acquired, a T-strap is all that is necessary to cover the genitals. If the exposure is begun in the winter, a blanket should be used instead of a sheet. When the sun is very hot, a damp cloth or ice-cap may be placed on the patient's head. Orthopedic apparatus should be so constructed as to permit the sun's rays to reach the skin.

In summer when the sun is intensely hot, the exposure should be started as early as possible in the morning and should be resumed *in the late afternoon, omitting the midday hours.* In winter the best time for the exposure is in the middle of the day, beginning about 10 a.m. The exposure should be given as nearly as possible at the same time each day. When the patients are debilitated and when the weather is cool, exposures are made on the first day for five minutes every two hours. The feet and lower four inches of the legs are uncovered and exposed to the sunlight. Both the front and back surfaces of the body should be exposed and the areas alternated by lying first on the back and then on the abdomen. On the second day the feet and legs are exposed as described for the first day. The sheet is then raised so that a new surface four inches above is exposed and the treatment is continued for three or five minutes longer. Thus the time of exposure on the original area is increased to eight or ten inches. Both front and back surfaces of the legs should be exposed. On the third day the time of exposure over the feet and legs is increased to fifteen minutes, the

The physical and physiologic effects of sunlight have been studied extensively. Downes and Blunt showed that light exerts definite bactericidal action and that *the shorter light rays are easily absorbed,* and produce intense hyperemia, resulting later in pigmentation. Light, in all probability, acts indirectly on the body by means of the cutaneous nerves and blood vessels, as no evidence has been advanced to show that ultraviolet radiation can penetrate into the depths of the body if employed in dosages suitable for clinical use. The hyperemia of the skin relieves the internal organs and tissues of much of their

FIG. 5—Heliotherapy at the Crippled Children's Hospital, Memphis, Tenn.

vascular contents, causing increased warmth, blood volume, and circulation through the local area. With the production of cutaneous hyperemia, there is developed a more pronounced bacteriophagic and bacteriologic action of the blood stream.

In addition to the analgesic effect of the cutaneous hyperemia, the direct action of light upon the nerve endings in the skin may also produce reflexly physiologic changes within the body. Constant exposure to sunlight induces pigmentation of the skin, stimulates the physiologic functions of the skin, and causes the skin to be more resistant to infection from without. The exposure also raises the calcium and phosphorous content of the blood, restores the natural tone of the muscles, and causes an increase in density and dimension of the osseous structure. In addition, the sun treatment promotes greater respiratory activity which improves the heart action and the general

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time over the second area to ten minutes, and a new surface of four inches is exposed for three or five minutes. The time and surface area on both sides of the body are gradually increased in this manner until the entire body acquires tolerance to the sun and air and the proper dosage is secured.

Dosage.—As the reaction of different individuals varies, no arbitrary rule can be made as to the maximum dosage; some patients will improve on ten hours daily, while others can stand only six. In robust patients, when the temperature is above 23.8° C. (75° F.), the tedious process of acquiring tolerance may be omitted and the entire body exposed for five minutes every two hours, increasing the amount from three to five minutes each day until the maximum time is reached. Especial care must be taken not to burn or blister the skin, for if this occurs the treatment will not only be delayed but the patient will be discouraged and unnecessarily annoyed. If the patient has been sunburned, give a shorter exposure the next time. The length of time given for exposure is for full sunshine. If the patient is exposed ten minutes on a partly cloudy day and fifteen minutes the next time on a hot sunny day, he may be burned, even though the schedule is followed exactly. On rainy days the sun should be utilized whenever it shines. When the weather is cloudy, the exposure is not so effective, but should be continued routinely. The length of time may be increased on cloudy days after the patient has acquired tolerance.

Heliotherapy must not be indiscriminately administered or much harm may accrue. If headache, weakness, nausea or fever is present, the time of exposure should be decreased or the treatments discontinued temporarily, to be resumed later and more gradually. If the sun is very hot, decrease the time of exposure. Never keep the patient out if he is cold or chilly. Bring him in at once and see that he is well warmed. If the patient has discharging sinuses or open wounds on the body, the bandages may be removed and the part exposed, care being taken to keep flies away from the wound and from the soiled dressings. The discharge from sinuses is markedly increased after insolation, but later subsides and becomes less purulent as healing progresses.

Pigmentation, or tanning of the skin, is essential to success and synchronous with clinical improvement. Patients who pigment readily improve more rapidly than those who do not pigment, and conversely, response to treatment is not so satisfactory in those who do not tan or freckle, as blondes, particularly red blondes. Brunettes will become a mahogany brown; the blackest negroes become a shade blacker and there is slight danger of sunburn. Pigmentation is not merely a protective agent against the caustic action of the chemical rays of the spectrum, but it is an important factor in favoring penetration of light, inasmuch as it changes a white reflecting surface to a dark light-absorbing one. Rosselet suggests that possibly the pigment in the skin transforms the long light waves into shorter waves of deeper

penetration, thereby reaching the superficial blood vessels. Other authorities deny that sufficient evidence has been produced to prove that pigment transforms invisible rays into chemical rays, although Mayer states that it may well allow a greater and more prolonged utilization of the visible radiations. Another theory is that the pigment absorbs the visible and ultraviolet rays and converts them into heat which activates the sweat glands; the sweat in turn protects the body from excessive heat by evaporation. Whatever the exact mechanism is, it is well known clinically that individuals who pigment well tolerate more prolonged application of light and withstand exposure to extreme degrees of heat and cold more easily.

The influence of heliotherapy on the pathologic process is demonstrated by the roentgenogram. About the time pigmentation is established, there is increased activity, as denoted by the breaking down of the osseous structure. Later absorption of necrosed areas will be observed, the affected bone becoming more opaque and, after a few months' exposure, rapid destruction of the joint surfaces is observed. By the end of six or eight months the bone is often more dense than normal with beginning fusion of the joint. The inflammatory exudate surrounding the affected areas becomes irregular and gradually diminishes in circumference, or at times undergoes calcification. This rapid evolution is probably due to the removal of devitalized tissue by natural forces, stimulated by the tonic action of the sun's rays, and might easily be mistaken for an acute exacerbation. This hastening of the evolutionary process is also evident in those cases with secondary infection and draining sinuses, the discharge of which is markedly increased after insolation, but later subsides and becomes less purulent and more serous as healing progresses.

The length of time required to secure satisfactory results varies, but excellent results have been obtained after as short a time as five months. In all tuberculous affections overtreatment is advisable. In every case at least two seasons of nine months' insolation should be given, but in the majority, three years of continuous treatment. When the finances of the patient permit, there should be a close pursuit of the sun for the entire twelve months of the year, which can be acquired by moving to warmer climates, as Florida, southern California, or Texas during the winter season. A change of climate is often more essential in bone than in pulmonary tuberculosis, as many clinicians believe that climate has no influence on the latter condition.

Actinotherapy.—In certain localities where the amount of sunshine is limited and during the months when direct exposure to the sun's rays is not practical, artificial heliotherapy may be employed, although the same beneficial results are not to be expected. Among the various sources of artificial light are the carbon arc light, the quartz mercury-vapor light and the roentgen ray. In deciding which is the best of these when obliged to use artificial light, either wholly or

in part, preference should be given to the light that gives a spectrum most nearly resembling that of the sun, or which exhibits the greatest number of those rays which typify the therapeutic quality of sunlight. The carbon arc light alone exhibits a continuous spectrum like that of the sun, all others showing a line spectrum—that is, a spectrum con-

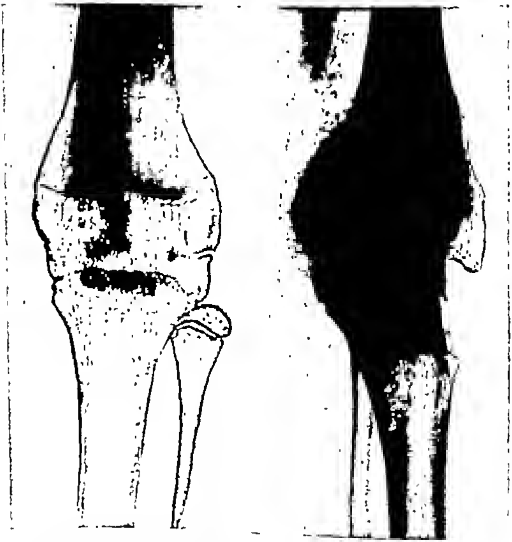

FIG. 6—Roentgenogram showing result of operative fusion of knee for tuberculosis. Anteroposterior view. Surgical treatment was employed in conjunction with heliotherapy and the disease has been completely arrested.

FIG. 7—Same as FIG. 6. Lateral view.

taining luminous lines broken by dark intervals. From experiments conducted at the Finsen Medical Light Institute in Copenhagen, the carbon arc light has been proved to be the light that most nearly approaches sunlight. Not only does it exhibit a continuous spectrum rich in blue, violet, ultraviolet, and especially the long wave ultraviolet

rays, but it is also highly efficient in both infra-red and luminous red rays.

The Carbon Arc Light.—The light described by Strandberg and Reyn as the standard model at the Finsen Medical Light Institute is so constructed that it can carry an extremely powerful current. The power used is direct electric current of 75 amperes and the lamp requires 55 volts. The carbon electrodes are very thin, as it has been found that the thinner the electrodes, the more intense the white light and hence the richer in chemically active rays is the light radiated from the crater which forms on the upper or positive electrode. The rays from this crater are essentially the light used and they form a cone of brilliant light under which the patient must be placed.

The room in which the treatment is given should be 5.4 by 7 meters and 4 meters high. The floor should be of noninflammable material and the wall painted a dark color, so that neither patient nor staff may be affected by the heat rays reflected from a light colored wall. Whenever possible a skylight or other ventilating device should be arranged to carry off the heat and fumes from the lamp. The windows should be constructed so that they can be opened from the top without being opened at the bottom in order to avoid drafts. The lights are suspended so that the distance from the anode to the floor is about three feet. The patients are nude and are placed in a circle about the lamp, being approximately four feet from the anode. Their eyes should be protected by goggles with very dark amber lenses. The dosage must be carefully timed, and the operator should remember that lamps made by different manufacturers vary greatly in their intensity. Strandberg, at the Finsen Medical Light Institute, recommends for adults an initial exposure of from twenty-five to thirty minutes over the whole body. This dose is increased by from ten to fifteen minutes every other day until the full period of two and one-half hours is reached. The dosage with the American-made carbon arc lamp is usually much less than that advised by Strandberg. The lamp used at the Northwestern University Medical School produces a skin erythema in one minute at a distance of four feet. In children the initial exposure must be of much shorter duration and the dosage more gradually increased. When the maximum time is established, this dosage should be continued unless the patient misses several treatments. When this occurs, the time of exposure on resumption of treatment should be reduced according to the time lost, the physical condition of the patient and the amount of pigmentation still present. As in heliotherapy, treatment should be given continuously for from six months to two years.

Quartz Mercury-Vapor Light.—The mercury arc is especially rich in the extremely short actinic or ultraviolet rays which have a rapid germicidal action. It does not, however, give a continuous spectrum and the long rays are entirely absent. All clothing is removed from the patient and amber eyeglasses or goggles are worn to protect the eyes. The patient is placed in a recumbent position and subjected

for three minutes during the first treatment to the action of the rays of the lamp, which is suspended twelve inches above the patient. As with the carbon arc lamp, it must be remembered that quartz mercury-vapor lamps made by different manufacturers vary in their intensity and that the same lamp loses strength gradually with use so that when new, the time of exposure must be shorter than after the lamp has been burned for a while. In children, one minute with the lamp suspended 30 inches above the patient may be sufficient when using a lamp

FIG. 8—Roentgenogram of shoulder after surgical arthrodesis combined with heliotherapy. The patient is well clinically.

for the first time. If the patient can be turned, the back is also exposed to the light for a similar period of time. The time of treatment is increased one to three minutes daily, as the skin acquires tolerance to the rays, until one hour per day is reached, or pigmentation is established. As in heliotherapy, improvement is synchronous with pigmentation, and response to treatment is not so satisfactory in those who do not pigment or freckle. The dosage must be regulated to each individual, the maximum for any patient after tolerance is acquired being six hours per day. The contraindications to the use of all light

baths are severe forms of heart disease, arteriosclerosis, nontuberculous nephritis, gastro-intestinal disturbances and acute illnesses with a temperature of over 38.3° C. (101° F.), unless the cause of the fever is known and not considered to be a contraindication.

Marine Treatment.—Marine treatment is the routine bathing of the tuberculous patient in sea water, and is of tonic value, especially when combined with heliotherapy. The atmosphere absorbs a certain percentage of all kinds of rays, although not an equal amount of each kind, the degree of absorption being greatest in the case of the shorter waves. Therefore, at sea level sunlight will contain comparatively few ultraviolet rays and will contain comparatively many blue, violet, luminous and heat rays. The effect of sunlight at the seashore, however, is greatly enhanced by the reflection from the white sand and from the mirror action of the surface of the water. Equally good results are, therefore, secured at the seashore as in the mountains.

Roentgenotherapy.—Treatment with the roentgen ray is considered by some authorities to be of value in the conservative therapy of bone and joint tuberculosis. Roentgenotherapy is not a specific treatment, but is considered to be successful only when there is a tendency to spontaneous recovery. The results are better in diseases of the small articulations and bones than in diseases of the larger ones. Tuberculosis of the toes, fingers, hand, foot, ankle, wrist, sternum and ribs is improved by this method. The elbow may also be treated to advantage. The shoulder and knee are less amenable and treatment is not so satisfactory in disease of the hip, sacro-iliac articulations, and spine. In treating these latter conditions, deep therapy apparatus is essential. Hornicke recommends, in most cases, one third of an erythema dose, provided that no complications are present. The number of irradiations should be so regulated that the total dose for six weeks of treatment will not exceed one erythema dose. When this amount has been administered and repeated three times, further treatment should be discontinued for several months. The optimal dose varies in individual cases. It is, therefore, advisable to begin with small doses and gradually to increase the amount of irradiation according to the patient's requirements and tolerance. If abscesses or fistulas are present, the dosage must be smaller and more carefully regulated. Overtreatment may lead to rupture of the hyperemic skin over the abscess with the formation of an ulcer, or the sinuses may close with consequent retention of the pus. As in the treatment of tuberculosis with heliotherapy and actinotherapy, roentgenotherapy *must be combined with intensive general treatment.*

Operative Treatment.—Excision of the tuberculous focus is rarely feasible, even though the diseased area is small, unless it is possible to excise an entire bone, as, for example, excision of the astragalus in tu-

berculosis of the ankle joint. Resection of the joint for the purpose of eradication of the disease process is obsolete in both children and adults, but it is especially contraindicated in children, not only on account of affecting growth by injury or removal of the epiphyses, but because the process is very rarely arrested. In adults, excision may be indicated in elbow, but seldom, if ever, in other joints. Unless some definite advantage is to be gained, indiscriminate operations may have a deleterious effect. Definite sequestra when demonstrated by the roentgenogram may at times be removed with beneficial results, and sinuses may be excised or properly drained.

Tuberculous obscesses should be treated conservatively unless rupture is inevitable or life is endangered by mechanical pressure on vital organs. The treatment consists of aspiration of the abscess when fluctuation is present, after which continuous compression is made by bandages. When secondary infection by pyogenic organisms is a complication, as evideoced by constitutional symptoms of bigb temperature and other indications of sepsis, incision and drainage should be carried out along the same principles as in the treatment of pyogenic abscesses. The injection of various antiseptics into the abscess is employed routinely by many surgeons but is of doubtful efficacy. Sinuses may be defined by injection of opaque substances, such as bismuth, after which excision or drainage may be instituted.

The purposes of surgical arthrodesis are practically the same as those of nonoperative measures—to enforce rest with fixation and to prevent deformity until nature encapsulates the pathologic process. By means of bony fusion a better fixation is secured and it has been proved by clinical experience that the arrest of the process is more apt to be permanent when osseous ankylosis results from any form of treatment. However, emphasis cannot be too strongly made that conservative treatment, as mechanical fixation and all measures tending to elevate the stamina and the natural resistance of the patient, must be constantly and rigidly employed, both in adults and children, and that fusion is only a valuable adjunct and must not be viewed in the light of a curative agent. The chances of a permanent recovery are much greater when such measures as heliotherapy, proper diet, fixation by orthopedic apparatus and operative measures are combined judiciously.

The indications for fusion operations vary in different joints, but at the present time arthrodesis is advised for tuberculous joints in all patients above the age of fourteen years, with the exception of the elbow in which satisfactory results may be obtained by excision. In young children between the ages of three and five, when tuberculous arthritis is most prevalent, the induction of intra-articular fusion is difficult. Time is also of less economic importance to the child than to the adult and longer periods may be devoted to conservative measures. The induction of osseous fusioo is influenced by the stage of the existing pathologic process. The early stage, before there is extensive

destruction or osteoporosis, and the late residual stage after the osseous structure has returned to normal density, are the most favorable periods to induce fusion. In the stage of active osseous destruction, with acute symptoms, often complicated by abscess, the likelihood of inducing bony union is less, and there is also the possibility of converting a closed tuberculous process into an open one with secondary infection. Fusion in the presence of an active pyogenic secondary infection should be undertaken with great caution. The probability of relighting a virulent active process, even though it is apparently arrested, is much greater in those in whom such secondary infection has occurred. The operation may be employed also in conjunction with extra-articular osteotomy for the purpose of correcting deformity when present.

Prognosis.—The time required to effect a cure naturally differs according to the severity and locality of the affection. Broadly speaking, it can be stated that tuberculosis is arrested in children more quickly than in adults, and that affections of the small joints are more rapidly and easily healed than those of the large joints. Excellent results are sometimes obtained in six months, but, as a rule, two years or more are required.

The prognosis for recovery with a practical degree of function preserved is unfavorable, and is possible theoretically only in those in whom the process is arrested and encapsulated before the joint is involved. With conservative as well as with operative treatment, observation is required for a period of at least three years. The only definite promise to be made as to the efficiency of local treatment is that deformity can be prevented or restricted to a minimum degree, and that the process will probably be arrested In those receiving no treatment, or inefficient treatment, the course is more prolonged and indefinite, resulting in deformity and permanent disability. The results can best be expressed as arrested instead of cured, since dormant or latent foci may remain indefinitely, regardless of the treatment employed.

Uncontaminated tuberculosis is rarely fatal unless there is invasion of a vital center, as the cerebrospinal system. Death is more frequently due to secondary infection or other complications. The prognosis for life is better in children than in adults. The mortality is greater in involvement of the spine and hip joint, and less in the upper than in the lower extremities. When abscesses are uncomplicated by secondary pyogenic infection, the prognosis is very slightly affected. With secondary pyogenic infection, the process is much more prolonged and the prospect of recovery materially reduced. Amyloid degeneration as a result of continued sepsis is usually fatal. Pulmonary tuberculosis, when associated, lessens the chances of recovery, but runs a milder course than when tuberculosis of the lungs occurs independently. Tuberculous meningitis is an infrequent but fatal complication.

In adults, early operative measures for the purpose of fusing or immobilizing internally the affected joint will often arrest the local process. In children, there exists at present a difference of opinion as to the advisability of fusion; the preliminary reports are most encouraging, but sufficient time has not elapsed for definite conclusions to be reached. The scientific application of the sun's rays or artificial light should always be employed. Undoubtedly, fresh air alone has a beneficial effect, but the relative improvement is much greater in those treated by heliotherapy than in those treated by fresh air without removal of the clothing. The results are also more lasting with less danger of recurrence than with any other method.

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CHAPTER FIVE

PHYSICAL THERAPY IN THE TREATMENT OF FRACTURES

Philip D. Wilson, M.D.

Introduction

The place of physical therapy in fracture treatment has been a matter of controversy, and different opinions have been expressed. Some experienced surgeons consider physical treatment unnecessary or even harmful, holding that only active, voluntary effort on the part of the patient actually counts in restoring function. Others regard physical therapy as a luxury, and doubt that the possible benefits justify the expense, especially in patients of moderate means. Still others consider physical therapy dangerous from the psychologic standpoint, in that it places undue emphasis upon the treatment of short duration administered by the technician and tends to minimize in the patient's estimation the value of his own efforts, usually just at the time when active coöperation is most necessary in obtaining a good result.

On the other hand, physicians who are experienced in the art of physical therapy consider it absolutely indispensable in the treatment of fractures. They point to the harmful effects of treatment by immobilization alone as evidenced by the many patients with impaired function who drift into their hands many months after injury, having been treated by every method except physical therapy. They criticize the neglect of many physicians to consider the physiologic requirements of the muscles, the joints and the circulation, and for believing that the only indications for the treatment of fractures are complete reduction and prolonged fixation. They feel that a considerable proportion of fractures can be treated by physical therapy alone and with vastly better results than frequently are obtained by physicians who place their reliance entirely upon retentive apparatus.

In between these extreme views may be found all shades of opinion in respect to the value of physical therapy in fracture treatment. For the most part, however, the rank and file of the medical profession are unable to form an opinion and admit a complete lack of knowledge. In the minds of most of these the term *physical therapy* evokes the picture of an establishment fitted up with a large assortment of complicated electrical machines, variously colored lamps and hydrotherapeutic apparatus. They feel vaguely that all of this machinery may

have some therapeutic value, but mistrust it for their patients on the grounds of expense, inability to direct the treatment, and the belief that after all it is not necessary. They are unable to dissociate the ideas of physical therapy, electricity and machinery. For the most part, they do not employ physical therapy for the treatment of fractures except when, usually as the result of some fault of treatment, a patient has obtained an unsatisfactory result, and nothing else in the way of treatment remains to be tried.

The student who is seeking the truth about the value of physical therapy in fractures will quickly dismiss many criticisms that obviously proceed from ignorance. On the other hand, he will not be able to dispose in this summary fashion of the widely divergent opinions that have been expressed by experienced and reputable surgeons and physical therapists. If he delves more deeply into the subject, however, he will find that it is possible to reconcile even these differences and that the opponents are in reality proceeding from different premises and arguing about different things. The physical therapist shares with the surgeon his high estimate of the value of active voluntary effort in regaining function at a certain stage of fracture treatment, but he also knows that if he waits until the time when active motion can be performed, to employ physical therapy, he will have missed the golden moment for helping the patient. The surgeon is sceptical of the value of physical therapy chiefly because he has never used it until after consolidation of the fracture has been obtained, and the physical therapist would be the first to admit that it can accomplish little at this time and should not be used except in so far as to teach the patient how to help himself by active exercises. The two methods are complementary, not competitive. When the physical therapist advocates massage and mobilization of the fresh fracture, he is speaking of a highly specialized technic totally different from the deep massage and vigorous movements that the surgeon has in mind. The surgeon labors under the impression that early physical therapy means turning over for treatment, by mere technicians, patients with loose, freshly reduced fractures; whereas the physical therapist has in mind only that many fractures are susceptible of treatment by this method, that the surgeon should learn to apply this specialized technic himself and that it should be stored in his armamentarium along with the other tools of his trade to be used according to the indications of the individual case.

Much of the criticism of physical therapy arises from a failure to distinguish between the agency itself and its use. Physical therapy can be of great value in the treatment of fractures when properly employed, of that there is ample proof. It can likewise do harm when improperly used. It can also fail to be of any benefit whatever when employed at the wrong time. Physical therapy has frequently been misused in the treatment of fractures, but instead of reacting to the detriment of physical therapy, this should serve as a stimulus for acquiring sufficient knowledge of the art to be able to employ it

properly. No physician who treats fractures can really say with truth that he does not employ physical therapy. The prescriptioo of heat at one or another time in ooe form or another is practically universal; so also with home massage and exercise. By so much, the physician admits that he believes in physical therapy. All that remains necessary to enlarge his visioo of its sphere of usefulness is to inform him more specifically of the actioo of its various agencies, and to relate these effects to the pathologic and reparative changes of fractures, in so far as possible.

While much of the confusion that hinders a just evaluatioo of physical therapy may be traced to the lack of knowledge of the physician who treats the fracture, not a little arises from lack of knowledge of fractures on the part of the physical therapeutist. Many exaggerated claims have been made of the benefits to be derived from the use of various physical therapeutic agencies in the treatment of fractures, which cannot possibly be substantiated. Some are the result of enthusiasm, others require a less charitable explanation; all bring harm to the cause of physical therapy. Many agencies are used whose effects are uncertain, or io respect to the action of which experimental evideoce is lacking. The physician who is conversant with the problems of fracture treatment and is trying to steer his patient through the shoals and troubled waters of complications to the haven of a speedy convalesceoce cannot be blamed for refusing to ask the assistance of a pilot who insists upoo sailing only in uncharted channels.

The first principle of fracture treatment is reduction of the bony deformity, and after that comes treatment to secure healing of the fracture and to restore function. Of the various physical measures that are employed in treatment, by far the most important are two that are mutually antagonistic—rest and movement. Rest or immobilization is necessary to maintain reduction of the fracture and allow healing of the bones, while equally necessary from the standpoint of the muscles, joints, blood vessels and nerves is movement or mobilization to maintain and restore function. Indeed in the balancing of these two antagonistic principles lies the essence of fracture treatment, and it is because the requiremeots are of a conflicting nature that difficulty arises. Between the moment when the first cautious attempts at movement are begun, in a recently reduced fracture, and the later period when healing of the bones has been obtained and vigorous exercises can be prescribed lies an interval, often of many weeks, during which every detail of treatment must be maoaged with skill, and when any ill-considered step may bring disaster. It is not possible during this period to turn the patient over to a technician for physical therapy without endangering the result, and it is unwise to do it later unless the physician supervises the treatment in the closest manner. In the treatment of fractures it is impossible to separate the physician and the physical therapist. He will be the best physician who is instructed in the art of physical therapy, and the best physical therapist will be he

who combines this knowledge with that of the physician. Indeed, if physical therapy is to accomplish anything in the treatment of fractures, it will be because the physician is sufficiently impressed with its value to administer it personally in the first few days after injury, and to instruct and demonstrate to his assistants the methods he wishes to have followed in the later stages.

Physical therapy includes a number of agencies or modalities, each of which is capable of producing a definite physiologic reaction in the human body. In order to employ these successfully in the treatment of fractures, the physician must know what these agencies are, what they accomplish and when they can be used with benefit. He must be able to prescribe them in the same manner as he does drugs. When a physician prescribes medicines, he not only writes his prescription carefully, but he takes pains to refer the patient to a reputable pharmacy to have it filled. He instructs the patient how frequently and in what amount he is to take the medicine, and he arranges to have him report at regular periods in order to be able to watch his reaction and to modify the dosage if the reaction is unfavorable, or to stop the treatment altogether if it proves to be of no benefit. The same course should be followed when prescribing physical therapy; the treatment should be outlined in detail, and the directions followed minutely. When in doubt, consultation between the physician and physical therapist will prove of great benefit. To send the patient to a physical therapist with instructions merely to treat him, as is frequently done at present, is in principle almost as ridiculous as to refer a patient to a pharmacist with instructions to prescribe what medicines he needs.

It will be the purpose of the author in this article to point out the opportunities for physical therapy in the treatment of fractures, to show how fracture pathology may be modified by the physiologic reaction to the agencies that are employed, to stress the importance of early functional activity and to demonstrate how this may be obtained. Chief emphasis will be laid upon the various forms of massage and mobilization with the view to confining the discussion to those agencies of which we have the most knowledge. Of the various methods of electrical stimulation and treatment there will be but little mention, as too little experience has yet been acquired to make it possible to formulate directions for their use or to permit definite conclusions to be drawn as to their value.

Historical

Just Lucas-Championnière was the pioneer of physical therapy in the treatment of fractures. A surgeon, practicing in the hospitals of Paris, he became dissatisfied with the results obtained by the routine methods for treating bony injuries. The central principle around which these methods revolved was immobilization, and the more perfect the immobilization, the better was the treatment. Lucas-Championnière, however, observed that the patients who had been treated by these

methods kept coming back to the clinics for months and years, complaining of swollen limbs, stiff joints, pain and disability, even though their fractures had healed. He recognized that much of this was the result of prolonged fixation and the policy of treating the fracture as if the bone were the only constituent of the part, and the muscles, joints, vessels and nerves nonexistent.

He began experimenting with massage and movement in the treatment of recent fractures, commencing with minor bony injuries, such as those involving the shaft of the fibula, and then gradually, as he perfected the technic and gained confidence in the method, extending it to fractures involving more important bones as well. He found that with gentle stroking massage he could relieve pain even in the fresh fracture and secure muscular relaxation; with care, the joints adjacent to the fracture could then be moved passively through a wide arc of motion without causing pain. With regular repetition of these treatments, the part being splinted during the intervening periods, the patients recovered from their fractures more quickly and more completely than others whose fractures had been completely immobilized. When he extended the scope of the method to include more difficult fractures, such as those involving the lower end of the radius and the upper end of the humerus, the results proved equally impressive. It became quite obvious to him that early movement of the muscles and joints in the vicinity of a fracture maintained their suppleness, on the one hand, and, on the other, favored the circulation and nutrition of the member. He became convinced of the importance of early massage and mobilization in the treatment of fractures.

Lucas-Championnière [1] published, in 1889, a small pamphlet entitled "Le Massage et la Mobilization dans le traitement des Fractures," in which he summarized his experiences and observations and described the methods that he employed and their rationale. He considered mobilization the most important factor of this treatment. Referring to a limb, he said "movement is life." He believed that massage was merely a means to an end, that end being movement. He employed only the gentlest type of superficial massage, and the treatment was administered either by himself personally or by a medical student whom he had trained. Avoidance of pain was deemed essential. The massage brought about relief of pain and relaxation of muscle spasm. Its effects could not be explained upon mechanical grounds, as the massage was too light and superficial in character, and he advanced the theory that it acted reflexly through the nerves and that it brought about an exhaustion of the sensory endings. The massage was administered for from ten to twenty minutes, and, when muscular relaxation had been obtained, then mobilization of the neighboring joints was in order. The movements were performed passively, not actively, but only when the muscles were completely relaxed. The treatments were of short duration and were repeated daily or on alternate days.

The results obtained by Lucas-Championnière were remarkable, par-

ticularly in contrast with those obtained by the preëxisting treatment. In judging these results, however, it is well to remember that this was prior to the discovery and clinical application of the roentgen ray, and that the diagnosis of fracture was often faulty, and the control of reduction negligible. Bony deformity of greater or lesser degree was the rule rather than the exception after treatment. Lucas-Championnière's treatment probably did not lessen the bony deformity, but it did at least restore function, and in this respect it was far and away ahead of the usual immobilizing treatment. At the same time there has been a great misconception of his real attitude. While radical, he never took an extreme stand, or claimed that his treatment could be applied without modification to every fracture or that all splinting should henceforth be discarded. He did not discard all that he had learned in his surgical training, but on the contrary continued to use splints in loose and displaced fractures and to advocate operative repair in fractures, such as those of the patella, where that method obtained the best results. Only instead of making the fixation continuous, as was the general practice, he removed the splints at regular intervals for massage and mobilization. Above all, it must be remembered that he kept the treatment entirely in his own skilled surgical hands or in the hands of the medical students whom he himself had trained. He had no use for massage as ordinarily practiced, which he considered far too vigorous and painful, nor did he think it possible for even a trained technician to employ his methods satisfactorily. What he advocated was the early use of physical therapy—i.e., massage and mobilization—by the physician in charge of the patient, in conjunction with whatever other methods were indicated for the reduction and healing of the fracture.

While holding up a warning hand against the treatment of fractures by prolonged immobilization, he at the same time sounded a warning note against the injudicious and uninstructed use of his methods, which should be read carefully by any one who is tempted to be led away by enthusiasm for any particular method of treatment. Said he, "It is a serious matter to employ this revolutionary treatment, for the public is but little prepared to accept it, and the medical world is even less prepared than the public. I advise you, therefore, to act prudently, and to advance only by sure steps in order not to expose yourself to checks, to apply the method in such a manner that the good which may result therefrom will be evident to all."

Lucas-Championnière's work proved a turning point in the treatment of fractures. The importance of functional restoration began to be recognized and with this the necessity of treating all of the structures affected by the injury rather than the broken bone alone. Owing to the general misconception of what his attitude actually was, only a few physicians took up and applied his methods in their entirety, although few [illegible] time to fracture treatment have failed to be [illegible] by the changes he set in progress. Mennell[2, 3]

of London learned Lucas-Championnière's methods at first hand and has continued to employ them and to advocate them with the conviction born of a long and rich experience. His works on massage and the treatment of fractures are valuable contributions deserving the most careful study. I gratefully acknowledge my own indebtedness to them in the preparation of this article.

Other factors also have contributed their share toward placing emphasis upon functional recovery after fractures. The Industrial Compensation Laws have played a considerable part by bringing pressure to bear on reducing the disability period for various injuries. The Great War contributed a great deal to the improvement of methods for the treatment of fractures, more notably by the introduction of various types of open splints and the greater utilization of traction methods, particularly direct skeletal traction. It also aided the development of physical therapy, the accomplishments of which were seen and appreciated. Since the war the multiplication of the automobile and the increasing mechanization of industry have caused a formidable increase in the number of injuries. This has led to an intensified study of the means of reducing functional impairment after fractures and of securing maximum physical rehabilitation of the injured. Physicians are turning their attention to physical therapy in the hope of bettering their results with help from this source. There are great opportunities for the development of this art, provided that each step is made with caution and based upon a solid foundation.

Functional Restoration, the Goal of Fracture Treatment

The goal of all fracture treatment is the complete restoration of function in the injured part in the shortest possible time. When the injury is of a nature to cause irreparable damage, then the aim must be to minimize the functional loss, and particularly to try to avoid disabilities of a type to prevent return to the previous major occupation or activity. A perfect result implies that the injured part is as good as before injury, and that this has been attained without unnecessary loss of time.

The chief purpose of the skeleton is to provide a rigid framework for the soft parts and, together with the joints, to provide a mechanism which may be actuated by the neuromuscular apparatus. Interruption of the skeletal rigidity by a fracture leads to immediate loss of function, and function cannot be regained until rigidity has been restored by healing of the fracture. Restoration of skeletal rigidity is not alone sufficient, but there must also be restoration of the skeletal form; in other words, the normal alignment of the bone must be preserved. This is necessary, not only for esthetic reasons, but in order to maintain the normal anatomic relationship or architectural pattern without which the parts function imperfectly. The restoration of rigidity and normal form of the skeleton, however, is by no means all in the

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veins is stopped by the pressure of exudate, and there is a further accumulation of serum and lymph over a large area. Many of the phenomena are of reflex origin, as, for example, the edema from vasomotor paralysis and the *muscle spasm with pain and limitation* of joint movement. Blood clot forms about and between the ends of the bones and infiltrates all the adjacent soft parts, extending into the muscles and upward and downward along the fascial planes. Unclotted blood and serum gradually work their way to the surface, accounting for the extensive ecchymosis that is always seen in the region of a fracture. The formation of skin blebs is due to the vasomotor paralysis and the exudation of serum and lymph.

It needs to be emphasized that this condition of traumatic inflammation is not followed by repair but actually constitutes the first step in that process. Repair begins at the moment of injury. The blood clot filling the spaces between the bone ends and extending into and infiltrating all of the soft structures is soon invaded by leukocytes, fibroblasts and *newly formed capillaries originating from all the different* types of tissue involved in the injury, and becomes transformed into granulation tissue. It is important to note that at this stage there is apparently no difference in the character of the granulation tissue found between the bone ends and that formed in the soft tissues; they are one and continuous. Differentiation occurs later, when calcium salts are deposited in the tissue that is destined to become callus and connective tissue fibrils form in the intercellular spaces of that which is to become scar tissue, but even then the callus and scar remain firmly bound to each other. The scar formation and fixation of the muscles to the callus interfere with the contraction and extension of *the various muscles and hinder function.*

The old conception of a specific osteogenic cell, the osteoblast, derived entirely from other similar osteoblasts contained in the cellular space and marrow cavities of the ends of the broken bones has lost ground. According to modern views, bone is merely a form of connective tissue, and *the osteoblast is simply a* fibroblast in whose vicinity calcium salts have been deposited.[5] Furthermore, the bone-forming function of the osteoblast has been denied. It is claimed that the deposition of calcium salts in callus is entirely a physicochemical reaction dependent upon local factors, as, for example, a variation of the hydrogen-*ion concentration in that* region or a concentration of some catalytic agent or enzyme, such as, perhaps, the recently discovered phosphotase of Robison.[6] Evidence to this effect has been produced by Murray,[7] who succeeded in obtaining bone formation in muscle and fascia by the injection of certain salts of calcium and phosphorus. *This evidence has been* reënforced by the experiments of Huggins,[8] who was able to produce bone in the soft tissues by the transplantation of bladder epithelium.

treatment of fractures. Of equal importance for functional performance are the soft parts. The skeleton is only one part of the machine, the other parts being represented by the articulations, muscles, nerves and blood vessels. Without the joints to supply motion, the muscles power, the nerves control, the blood vessels fuel, the bones are merely so many inanimate levers. All participate in functional activity, and one structure is not of greater importance than any other. All must be considered in treatment.

Injury of the Soft Parts Accompanying Fractures

It is a common mistake in treating fractures to think only of the injury to the bone, and to forget or overlook the always-accompanying injury to the soft parts. To fracture a bone requires a considerable amount of force. The violence may act directly in the form of a blow or crush, in which case the first effect of the force is expended upon the soft structures before reaching the bones, or it may act indirectly, as by bending or twisting a part beyond its normal limits of elasticity, in which instance the giving way of the bone is accompanied by laceration of the overlying soft parts. Also severe strain is often imparted to the ligaments, sometimes at a point quite remote from the fracture. When the violence is severe enough not only to fracture the bone but to displace the fragments, additional damage is done to the soft parts by the temporary continuance of the force after the resistance of the bone has been overcome. An extreme example of such violence is seen in the case of a compound fracture. Here the overlying soft parts are completely ruptured, including the skin, and one can readily appraise the extent of the damage to the muscle and other soft tissues. In the majority of fractures that are classed as simple, the soft-part injury is just as great, though concealed from one's eyes by the fact that the integument remains intact. There is extensive laceration of soft parts, including muscles, blood vessels and fascia. In certain instances, either the main nerve or blood vessels may be torn, or both at the same time, resulting perhaps in paralysis, partial or complete ischemia, or gangrene.

Pathology and Repair of a Fracture

The key to the understanding of fracture treatment lies in a knowledge of the pathology of the lesion and of the changes that occur during the process of repair.[4] When a bone is broken, a condition of traumatic inflammation is produced. Hemorrhage occurs from the torn vessels of the bone marrow, periosteum and adjacent soft parts. The blood vessels dilate as a result of vasomotor paralysis, and lymphatic drainage is arrested. The swelling due to hemorrhage is further increased by exudation. The return of venous blood in the unruptured

Principles of Fracture Treatment

The requirements for fracture treatment are complex and difficult to fulfill. The ideal treatment could only be attained by a miracle which, without the necessity of any surgical intervention, would restore the displaced fragments to normal position immediately after the injury, would maintain them in perfect alignment without the use of splints or other apparatus and so solidly that healing would proceed while at the same time full use of the part with motion of the adjacent articulations could be permitted. This represents an ideal impossible of attainment, but it also gives us a goal at which to aim, and the more nearly our treatment can approach it, the better it will be.

The chief principles of fracture treatment may be stated as follows: first, restoration of anatomic form as soon as possible after injury; second, maintenance of alignment and fixation of the fracture during the period of healing; third, institution of measures to overcome the circulatory disturbance and to maintain and develop function, beginning at the earliest possible moment after injury and continuing until complete recovery is obtained.

Importance of Reduction of the Fracture

Restoration of a fractured bone to its normal anatomic form is essential to good functional recovery. Not only is it true that fractures which are properly reduced unite more surely and rapidly than those that are allowed to remain in vicious alignment, but the condition of the adjacent soft parts is also improved, and there is commonly to be noted less swelling and circulatory disturbance. Since the traumatic inflammatory process that is initiated by a fracture reaches its peak within 48 hours, it is evident that the pathologic changes can be influenced only when the reduction is performed within a few hours of injury. As a matter of fact, reduction becomes increasingly difficult with every hour that elapses. The muscles and fascia become infiltrated with exudate and rapidly lose their extensibility, the tissue spaces become filled with lymph and fibrin, and blood clot envelops the ends of the bones and renders almost impossible the meshing of interlocking fragments. The use of more force is necessary to accomplish reduction, and this causes fresh hemorrhage and additional trauma to the soft parts. When the changes have progressed to the stage of organization or beginning callus formation before reposition of the fragments is accomplished, then still greater force must be used, and the amount of damage done is proportionately increased. Repeated reductions, necessitated by the failure of previous attempts, are enormously harmful and result in an extension of the inflammatory changes and an increase in the severity of the reaction. To promote functional recovery, it is of the highest importance to employ every measure that tends to minimize injury of the soft parts and to reduce cicatrization and cir-

The calcium salts that are deposited in callus seem to be derived chiefly from local sources, *from the autolysis of necrosed bone* at the ends of the broken fragments. Evidences of rarefaction and absorption here are the signs of normal progress of the healing process. For practical purposes the amount of calcium salts derived from the blood stream is relatively small and unimportant. The effect of this concept is to reduce fracture healing to a purely local process, the success of which is dependent upon local factors and only slightly affected by the general physiology of the body or by states of the body. If true, as appears probable, then this view eliminates the long list of general causes that have always been brought forward in explanation of nonunion and renders superfluous therapeutic procedures directed toward improving calcium metabolism.

Whatever may ultimately be proved to be the fact, the granulation-tissue mass between and about the bone ends gradually becomes converted into osteoid tissue. The intercellular spaces become filled with a homogeneous ground substance, the preosseous tissue, while scattered here and there are small islands of cartilage. Gradually calcium salts are deposited in the ground substance and cartilage, and the callus becomes hard. Bone tissue has been formed, and the union of the fracture is complete.

The time required for fracture healing is usually from three to eight weeks, depending upon the bone involved and the situation of the fracture in respect to cancellous or cortical bone. The process is quicker in children than in adults, and somewhat slower in old age. Callus formation may be delayed by local conditions which hinder the formation of granulation tissue, such as lack of surrounding structures from which it may spring, as in fractures of the neck of the femur and of the carpal scaphoid, or interference with proper blood supply or interposition of muscle tissue between the fragments. Operative interference at a late period, when the soft callus has to be cleared away in order to secure approximation of the fragments, is also likely to delay healing. There is considerable variation, in the local conditions upon which callus formation depends, between fractures of similar type in different individuals, and it is not remarkable therefore that considerable variation in the healing time should be encountered. The fact that union has not been obtained at the time it is expected is not a sign that it will not occur, but may merely indicate that the process of repair is proceeding more slowly than at other times. The amount of callus formed at first is excessive, but after the union has become solid, a further process of physiologic adaptation takes place. By revascularization and absorption the medullary cavity is finally reëstablished, the cortical layers demarcated, and the excess callus removed. The process of physiologic adaptation of the callus and restoration of bony contour is slow and may take as long as one or two years. Physiologic healing cannot be considered complete until this time has elapsed, even though anatomic healing has been obtained in a matter of weeks.

union. Each fracture must be visualized in terms of its eventual end-result, and the course chosen that will give the highest yield in terms of function. Impaction is a start already made in the healing of a fracture, and it should not be broken up without good cause, especially in aged patients. It is often the acme of wisdom to be satisfied with an incomplete reduction, as long as the misalignment is slight and not of a disabling type, rather than to pursue anatomic perfection at the cost of diminished or delayed function.

Reduction may be accomplished by manipulation, traction or operation. With the manipulative method the operator endeavors to replace the fragments by leverage, angulation or traction, relying upon manual skill supplemented occasionally by the temporary use of some mechanical appliance, to exert traction. When reduction has been accomplished, splints are applied to maintain the alignment. Obviously the method is limited in its application to fractures that are more or less transverse and only slightly comminuted and where reposition is likely to prove stable when obtained. It is employed particularly in fractures of the wrist, forearm, elbow, ankle, lower leg and hip. It is most successful when performed within two or three hours of the injury and with the aid of fluoroscopic visualization of the fractured bones. It requires skill and care to avoid injury of the soft parts from the use of too much force.

The traction method is used both to obtain reduction and to maintain alignment afterwards. It counteracts the deforming influence of muscular contraction and, by pulling the fractured bone out to full length and restoring the supporting tension of the soft parts, secures correction of the deformity. It should be employed in such a way as to obtain reduction immediately, before pathologic changes in the region of the fracture have progressed to a stage to render it difficult, instead of gradually over a period of several days. A traction force of sufficient amount to accomplish reposition should be applied initially, and, after reduction has been accomplished, this may be reduced to the lesser quantity necessary to maintain alignment. The same principle should be applied irrespective of what method of traction is employed or whether used in combination with traction splints or not. The traction method of reduction is used chiefly in fractures of the long bones such as the femur, both bones of the lower leg, the forearm and humerus. It is indicated in oblique and comminuted fractures involving the articulations and those of the phalanges. It is also of great assistance in difficult fractures which for one reason or another have not been reduced in the early period. Traction is not without danger, but it usually accomplishes its purpose with less damage to the soft structures than either of the other methods.

The operative method of reduction may be employed primarily in certain fractures, such as those of the patella and olecranon, where approximation cannot be secured in any other way. It may be employed as a matter of preference in other fractures such as those of the shaft

culatory disturbance in the region of the fracture, and for this, nothing is more effective than early reduction.

When fractures are allowed to heal without correction of the bony deformity, excess callus formation usually results, accompanied by greater fibrous fixation of the muscles. If the fracture is situated in the vicinity of, or involves, a joint, bony irregularity may block motion or alter articular contour sufficiently to render its use difficult. Malunion also leads to later functional impairment through its repercussion upon the mechanics of the body. Angular deformity causes the adjacent joints to be thrown into abnormal relationship and results in uneven bearing and strain. When healing is accompanied by overriding of the ends of the fragments, shortening of greater or lesser extent results, and this affects not only the bone but also the muscles, which almost never regain normal power. The Fracture Committee of the British Medical Association * reported, after a study of the late results of fractures in 1736 cases, that good functional results accompanied good anatomic results in over ninety per cent of the patients. Fair and even good functional results sometimes accompanied poor anatomic results, but usually only after prolonged disability time and when the particular and special types of deformity that lead to great crippling had been avoided. They stated that no method, whether operative or nonoperative, which did not promise a good anatomic result should be accepted as a matter of choice.

The importance of the reduction of the fracture at as early a moment as possible after injury must be accepted as a guiding principle of fracture treatment. As is the case with every rule, however, there are also exceptions to this. Some types of deformity are more disabling than others. Angular deformity and gross displacement with overriding are particularly likely to result in functional impairment. Simple lateral displacement without shortening, provided that there is sufficient contact of the bone ends to insure union, is much less likely to cause disability. The age of the patient also makes a difference, and more latitude may be permitted in the case of children than in adults. Below the age of fourteen the growth process tends to correct errors in bony alignment, and shortening of as much as one inch in the case of the femur may be entirely corrected at the end of two years. Angular deformity is just as pernicious in children as in adults and tends to persist.

All of these factors must be taken into consideration when treating patients with fractures. Complete anatomic reduction is always desirable, and no effort should be spared in obtaining this result in fresh fractures. On the other hand, it is easily possible to go too far in this direction. Each additional effort at reduction causes further trauma to the tissue and nullifies whatever start has been made in the process of repair. Fractures that have been subjected to repeated manipulation and finally to operative reduction are apt to show functional impairment later and have a decided tendency to go on to delayed or non-

mobilization unduly. The physician feels that he has solved the first problem of fracture treatment and does not recognize that the second problem, that of securing functional recovery, confronts him immediately.

Prolonged immobilization of the fracture is harmful to the soft structures involved in the injury and lays the foundations for slow recovery or permanent functional disturbances later. It has been pointed out by Drinker [10] that the accumulation of lymph in the tissues stimulates the growth of the connective tissue elements. Wherever there is prolonged venous or lymphatic stasis, an overgrowth of connective tissue results. Immobilization of a fracture promotes venous and lymphatic stasis by suppressing muscular contraction, upon which the venous and lymphatic circulations depend. Particularly is this true when the circulation has already been profoundly disturbed by the pathologic changes initiated by the injury itself and by the pressure of hemorrhage and exudate upon the uninjured vessels. Not only does the fixation of the muscles and joints interfere with the reëstablishment of the circulation and delay the absorption of the exudative products, but it favors the extensive development of scar tissue and adherence of the muscles to each other and to the bone.

In addition, it should be remembered that immobilization causes definite functional impairment even in the case of an uninjured, healthy extremity. Siegal and Sheboya, as well as other investigators, going as far back as 1866 (Moll [11]), have clearly demonstrated that if the bony attachments of a skeletal muscle are left immobilized for several days, so as to prevent the changes in length that normally result from spontaneous and reflex movement, there occurs a fixation of the muscle at the length thus imposed upon it. If taken early, this contracture can be overcome by active or passive movement, but if left untreated for some time, the damage becomes irreparable. This process, called *myostatic contracture* by Davenport and Ransom,[12] is dependent upon intact innervation. It is a condition of permanent shortening in resting muscle which is maintained in the entire absence of nerve impulses. A muscle affected by this condition cannot extend normally; neither can it contract as much as a normal muscle. Microscopically, such muscles show blurring of the striation, mottled staining and loss of alignment of the myofibrils. The muscle may become permanently damaged, depending upon the period of immobilization. The longer the period, the greater the damage, and the greater the amount of time and effort required to restore function.

Immobilization also gives rise to certain phenomena in respect to the articulations. The joint capsule tends to become thickened and contracted, losing some of its elasticity. The synovia begins to proliferate at the edge of the articular cartilage and to spread over the peripheral margin as in panous formation. When immobilization is discontinued and function resumed, the invading tissue begins to recede, and the joint capsule also gradually regains its flexible characteristics. To over-

of the femur or humerus, the bones of the leg or forearm or difficult fractures involving the articulations, on the grounds that it is likely to obtain a more perfect result than any other method. Resort is also had to it when previous efforts to secure reduction by other methods have proved unsuccessful. The operative method is necessitated in most compound fractures to get rid of soiled and devitalized tissue and prevent infection. Depending upon the situation and type of the fracture, the operative method may aim only at securing reposition of the fragments and rely upon external fixation with splints to maintain the alignment, or reduction may be combined with some form of internal fixation in the form of catgut, kangaroo tendon, wire, screws, nails, bone plates, bands, etc. Operative reduction should be made secure and no risk taken of secondary displacement which might invalidate the entire benefit of the operation. Operative reduction causes a certain damage to the soft tissues from the incision and exposure of the fracture, but this damage is often less in amount than that which would be caused by closed reduction. It is counterbalanced by the better reduction accomplished and the greater security that results, particularly when internal fixation is used. Operative reduction involves a certain risk, chiefly that of infection, and ought to be undertaken only by surgeons who have had special training for this work and who have at their command all the facilities in the way of equipment and skilled assistance that have been shown to be necessary for good results. Lastly, it needs to be emphasized that operative reduction is not to be regarded as a matter of last resort and deferred until all other methods have been tried. This generally leads to great delay, and the results will be much less beneficial than if the operation had been performed earlier. The physician should determine as quickly as possible what method of reduction offers the greatest chance of success and should proceed without delay to the use of that method irrespective of whether it necessitates operation or not.

Maintenance of Alignment of a Fracture

Reduction of a fracture, be it never so perfect, is of little service unless supplemented by appropriate measures to maintain the alignment afterward. This necessitates the use of external fixation either in the form of plaster-of-paris casings or of splints of different materials and types with or without traction. Redisplacement of a reduced fracture represents a real disaster, and the more completely the fragments are fixed, the less will be the danger of such a mishap. The formation of callus takes time, and if the policy of fixation is relaxed for a minute until consolidation is obtained, the alignment of the fracture may be lost. Furthermore, movement of the fragments may retard healing. Consequently when a fracture has been reduced and splinted, and the alignment has been proved to be satisfactory by the postreduction roentgenograms, there is a great tendency to prolong the im-

stimulated. When a fracture of the bones of the lower leg or of the shaft of the femur fails to unite within the usual time, a procedure frequently adopted is to apply a weight-bearing brace and encourage use, and bony union often results. All of these splints and braces permit a limited amount of movement at the site of fracture, and it is easy to start from this point and argue that movement stimulates fracture healing.

On the other hand, there are facts that point to the conclusion that when the approximation of a fracture is perfect and the fixation rigid and as complete as possible, then union is much accelerated. In the usual fracture the conditions are so favorable for callus formation that healing may occur even in spite of a little movement. In fractures of certain bones, however, such as the carpal scaphoid or the neck of the femur, the local conditions are unfavorable, in that callus formation must proceed from intrinsic sources entirely without help from the adjacent soft structures, and the blood supply to one of the fragments is scanty and frequently entirely lacking. Here failure of union is the common result of failure to immobilize, and all authorities agree that the more complete the immobilization, the greater the chance of obtaining union. Turning to fractures in other regions, it is not difficult to find many examples of nonunion where the responsibility can be traced directly to the door of repeated manipulations or of too much movement. While fractures of the long bones in both animals and men may heal without immobilization, it is to be noted that this is accompanied by bony deformity with overriding of the fragments. When displacement of a fracture is allowed to proceed without interference, the shortening finally reaches a maximum, and the fragments arrive at a point of relative stabilization. In this position, but not without it, is healing likely to take place. Such a result is not likely to be accepted willingly by the average patient, and to obtain healing without deformity, the wise physician will always employ immobilization. Similarly the explanation of the benefits that result from the use of weight-bearing splints or braces in fractures of the lower extremity is to be found in the improvement of the circulation and the overcoming of bone atrophy, which counterbalance and outweigh the harmful effects of such slight movement as cannot be prevented at the site of fracture.

One must conclude, from a review of all the evidence, that rigid immobilization of the fracture with good approximation accelerates bony union, but that, on the other hand, callus will usually form even in spite of a little motion of the fracture. With the microscopic picture of bone repair before one's eyes, it is easy to understand that movement of the fragments, while the callus is soft and in a formative stage, is likely to result in rupture of many of the small vessels and lead to an increase of the connective tissue elements which may be harmful later to union. If any motion is to be permitted during the healing of a fracture, it must be reduced to the very minimum.

come and counteract these changes, a considerable amount of time is required; during this period, use of the part is painful, and progress is likely to be delayed unless the patient exhibits considerable fortitude.

These are only a few of the more definite effects of immobilization upon the muscles and joints, and other examples of harmful results pertaining to the circulation and disuse atrophy of muscles and bone might also be given if it were necessary to make the picture complete. Enough has been written, however, to show the importance of avoiding complete immobilization of a fracture, whenever possible, and of reducing the period of fixation to the shortest possible time when no other method can be used.

One other question arises in connection with the subject of immobilization, namely, whether it is necessary in order to obtain healing of the bone. In the animal world there are found many examples of fractures that have healed without immobilization. Indeed, among the wild animals scarcely any other outcome after bony injury is possible save death. An animal that has fractured one leg keeps going on the remaining three legs until such time as the injured part has mended sufficiently to permit of some use. Necessarily, gross deformity results from such treatment, or lack of treatment, but this does not prevent callus formation, as is shown by the observation of many game hunters and other students of animal life, nor, according to report, does it seem to interfere very seriously with the function of the part. The situation with regard to the human animal is, of course, much more complex, but unfortunately examples are not lacking to show that unrecognized and untreated fractures may go on to union with deformity. Lucas-Championnière [18] called attention to the fact that callus formation almost never failed in the repair of fractures of the ribs, and yet that these bones were never completely immobilized. He also pointed out that healing regularly occurred in fractures of the femoral shaft, which, in his time, were treated only by extension without adequate fixation and where the fragments were necessarily moved at frequent intervals with the change of position of the patient in bed. Lucas-Championnière considered that a certain amount of motion was not inimical to callus formation, and went so far as to state that from his experience a certain amount of motion in fractures seemed to accelerate the formation of callus. Many surgeons now hold the view that complete immobilization is not necessary to fracture healing. As a matter of fact, it is rarely, if ever, complete, as practically all splints permit at least a slight amount of motion at the site of fracture. To eliminate all motion it would be necessary to apply the splints so tightly that there would be danger of pressure necrosis. In the modern functional treatment of fractures, early use of the injured part, protected by splints, is strongly advocated. In the case of certain fractures of the lower extremity, some surgeons employ weight-bearing splints at a period when the healing of the fracture is but little advanced, on the grounds that functional recovery is hastened and bony union is

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The location of the fracture is of considerable importance in determining how complete immobilization should be. Fractures through the shafts of the long bones are much more likely to exhibit delayed healing or nonunion than fractures through cancellous bone, the variation here probably depending upon differences in vascularity. Certain fractures are noted for delayed healing or failure to heal, as, for example, those of the scaphoid, neck of the femur, both bones of the leg at the junction of the lower and middle thirds, the shaft of the humerus in the middle third, and both bones of the forearm in the middle and upper thirds. Here immobilization should be as complete as possible and should be maintained as long as necessary even at the expense of functional consideration. On the other hand, fractures involving the other articulations, or in the neighborhood of the articulations, usually heal readily since they are situated in cancellous bone possessing ample blood supply. Such fractures require meticulous reduction, but once reduced, early mobilization may be permitted with benefit.

Knowing the harm that may be done by prolonged immobilization, yet having to make use of it in loose fractures in order to maintain reduction, let us consider how some compromise may be reached in the interest of promoting functional recovery. In general, fixation is accomplished by the use either of retentive apparatus or of traction splints. The former category includes plaster of paris apparatus, a variety of splints of different designs and materials, and some simple dressings of bandage or adhesive plaster. Under traction splints are included the various types of Thomas splints and special modifications of these intended for the arm, shoulder, leg and hip, and the so-called banjo splints for the fingers and toes.

When applying retentive splints to a reduced fracture, the first rule should be to fix a time for their removal. Especially is this necessary in the case of plaster-of-paris dressing. This time may have to be prolonged if union proves not as far advanced as expected, but nothing is worse than to prolong it without adequate reason. When using circular plaster-of-paris casings, it is always a safe principle to split them on two sides as soon as they have hardened. This guards against constriction and also makes possible the removal of the splints and examination of the fracture without unnecessary delay. Secondly, only those articulations should be immobilized whose movement would be inimical to maintenance of reduction or to fracture healing. Thus in fractures of the forearm or wrist it is unnecessary to fix the fingers or thumb, and active movement and use of the digits should be encouraged from the beginning. The same is true of the toes in fractures of the lower leg and ankle. Total fixation of the ankle is frequently not required, and a portion of the splint over the dorsum of the foot may be cut away to permit limited mobilization here without entirely sacrificing support of the foot. Movements of the shoulder or hip are not contraindicated in many fractures involving the extremities, but stiffening of these joints may occur during the period of fixation unless

adequate attention is directed toward preserving their function. Thirdly, in so far as the requirements of the individual fracture permit, those joints that are to be immobilized should be fixed in the optimum position for functional recovery. These are usually positions in which gravity will represent an aid instead of an obstacle to the recovery of motion. Thus the shoulder recovers motion more readily when fixed in abduction, the elbow in flexion, the knee in extension and the ankle in right-angle flexion. Frequently the necessity of maintaining reduction of a fracture imposes a different position upon one of the articulations, but the other joint may be fixed in accord with functional considerations. Lastly, it is frequently possible to remove the splints temporarily at regular intervals, beginning immediately after the reduction, to allow massage and mobilization. The fixation thus becomes interrupted instead of continuous. If the reduction is insecure with considerable danger of displacement, the splint on one side may be removed and this surface exposed for treatment while the fracture is supported on the other side. The splint may then be reapplied while the other one is removed to allow treatment. Healing soon progresses to the stage when the part may be lifted out of the splints altogether and supported manually while mobilization is performed.

Continuous traction or extension has been used for the fixation of certain fractures since ancient times. Although it overcomes shortening and secures reduction, it does not of itself provide immobilization unless used in conjunction with fixative apparatus. The traction splints devised by Thomas, and popularized at the time of the Great War by Jones, meet this need and provide both rigid external fixation and the opportunity for traction and countertraction. It is essential to employ suspension in order to derive the greatest advantage from the use of traction splints. Suspension means slinging the splint supporting the injured limb to an overhead frame by means of a system of cords, weights and pulleys in such a way that the weight of the injured member is exactly counterpoised and its mobility greatly increased. Traction is maintained by a cord passing over a pulley at the end of the bed and fixed to a weight. Traction-suspension is of great value as a physical therapeutic measure and also in promoting the patient's comfort. With proper arrangement of the apparatus, the patient is enabled to sit, lie or change position to a limited extent without disturbing the fracture. This greatly facilitates the nursing care, and the resulting activity is of benefit to the general musculature and circulation. It permits the mobilization of joints that would have to be fixed if retentive splints were used, maintains muscular activity, reduces swelling and generally hastens the recovery of function. The introduction and general adoption of the traction-suspension method for certain types of fractures marks one of the greatest forward steps that has been made in treatment looking toward the recovery of function.

The value of traction-suspension treatment has been well [illegible]

increased by the introduction of skeletal traction. By this procedure traction is applied directly to the bone by the introduction of pins, tongs or the small flexible wire of Kirschner. Skeletal traction, as contrasted with the ordinary method of adhesive skin traction, has three great advantages. First, the force is applied directly to the bone where its action is desired. There is no loss from diffusion of the force as in the case of skin traction; consequently the amount of force required is less. Second, the point of contact of the skeletal appliance with the limb is small, and as a result the entire region of the fracture and the distal part of the extremity are left uncovered. The wide access to the limb thus gained is of considerable importance in permitting the use of massage and heat, and also in the case of infected compound fractures in making possible examination and treatment of the wound. Third, when applied directly to the distal end of the fractured bone, it permits movement of the joints, not only above, but also below the fracture, and thus creates almost ideal conditions for functional treatment.

A third method of fixation that requires mention in any consideration of the ways of securing immobilization is that of internal fixation made possible by operation. One of the advantages of open reduction is that it paves the way for securing such complete fixation of the fracture that early movement of the neighboring joints may be permitted and other measures instituted to counteract and overcome the effects of trauma to the soft parts. In the case of relatively simple fractures where healing occurs rapidly, this may not constitute a sufficient advantage to justify prolonging the operation and introducing foreign material. In that case the surgeon will rely upon external splints to maintain the alignment following operation, but he should make an effort to begin removing them temporarily at an early period to permit movement. In the case of fractures that are likely to be displaced or that require a long period for healing, half of the benefits of open reduction will be lost unless some method of strong internal splinting is used. This usually means the introduction of metallic wire, screws, bone plates or nails. The great desideratum is that the fixation be made so secure by internal means that massage and movement can be started as soon as the patient has recovered from the operation. When this has been done, little in the way of external support is required, and protection is usually afforded either by retentive splints that may be removed for physical therapy or by traction-suspension apparatus which provides the opportunity for massage and movement.

Institution of Measures to Restore Function

There remains to be considered a third principle of fracture treatment that is of equal importance with the two that have been discussed previously, namely, the institution of measures to restore function. While atraumatic reduction of the deformity at the earliest

moment and maintenance of alignment afterwards by methods of splinting that minimize as far as possible the harmful effects of immobilization are of aid in obtaining functional recovery, their mode of action is more negative than positive in that they seek to lessen the ill effects of necessary treatment. Other measures capable of more directly influencing the pathologic changes in the soft parts must be adopted if the disability time of fractures is to be shortened and the functional results improved. The only measures at our command capable of accomplishing this purpose belong to the domain of physical therapy, and they should be included just as regularly in the treatment of fractures and employed with the same skill as are reduction of the fracture and splinting to maintain alignment.

When we consider the pathologic changes arising from a fracture, it is obvious that the immediate traumatic reaction and subsequent inflammatory process are of a reparative nature and have for their purpose the eventual formation of callus to heal the bone and of scar tissue to repair the injured soft structures. Much of the reaction in the soft tissues appears excessive, however, and out of proportion to the actual degree of damage. The soft parts are flooded with exudate and involved in severe circulatory disturbances that are inimical to the preservation of their function. The extension of hemorrhage between muscles and along fascial planes and into tendon sheaths leads through the organization of the blood clot to the formation of cicatricial adhesions, obliteration of gliding surfaces, and fixation of the mass of scar tissue to the callus with prevention of the shortening and lengthening reaction of the muscles. The pouring out of exudate during the inflammatory reaction increases the swelling already present from hemorrhage and adds to the embarrassment of the circulation by making pressure upon the veins and lymphatics and by blocking the latter with cellular products. The unavoidable immobilization of the fracture intensifies and perpetuates this condition by abolishing all muscular contraction, upon which the venous and the lymphatic circulation depend. As organization advances to cicatrization, the circulatory disturbances become fixed, owing to the blocking of the drainage channels by the newly formed fibrous tissue. Watson [14] expressed this conception as follows: "Blood extravasated into the soft tissues serves no known useful purpose. It is foreign material and in time is removed as such by the ordinary drainage media—the lymphatics and blood vessels. If these effusions and extravasations are not rapidly removed, organization will take place with the formation of adhesions between articular surfaces, between tendons and their sheaths and between nerves and the surrounding tissues producing 'matting' of the soft parts." All of these changes find expression during the convalescent stage of treatment, in swelling of the extremity, impaired circulation, joint stiffness and muscular weakness, and are reflected in the patient's complaint of continued pain and inability to resume normal activities.

As a matter of fact the time necessary to overcome venous stasis

increased by the introduction of skeletal traction. By this procedure, traction is applied directly to the bone by the introduction of pins, tongs or the small flexible wire of Kirschner. Skeletal traction, as contrasted with the ordinary method of adhesive skin traction, has three great advantages. First, the force is applied directly to the bone where its action is desired. There is no loss from diffusion of the force as in the case of skin traction; consequently the amount of force required is less. Second, the point of contact of the skeletal appliance with the limb is small, and as a result the entire region of the fracture and the distal part of the extremity are left uncovered. The wide access to the limb thus gained is of considerable importance in permitting the use of massage and heat, and also in the case of infected compound fractures in making possible examination and treatment of the wound. Third, when applied directly to the distal end of the fractured bone, it permits movement of the joints, not only above, but also below the fracture, and thus creates almost ideal conditions for functional treatment.

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was 206.5 days. These figures assume even greater significance when it is pointed out that a very large percentage of these cases represented only fracture-sprains or fractures without deformity, and very minor fractures such as those of the fingers or toes. While it is doubtless true that other factors such as psychologic and economic considerations play a considerable part in determining the length of the convalescent period in industrial surgery, it is nevertheless evident that the period of disability after fractures is longer than it should be and that the results of treatment are still far from satisfactory.

Progress in improving the surgical part of the treatment of fractures is being made as the result of organized propaganda and educational work carried out among the members of the medical profession throughout the country. While there still remains great room for further improvement along this line, I do not believe that this will solve the problem. I look to the more general and intelligent use of physical therapy, not by physical therapists but by physicians, as the means of making the next great advance in fracture treatment. Physical therapy when rightly used, that is, beginning in the acute stage of injury, is capable of influencing the pathologic changes of a fracture, particularly those affecting the soft parts, in a manner favorable to overcoming causes of delayed recovery. This belief is shared by many experienced students of fractures. Darrach [17] advised early massage both before and after reduction of the fracture and described the results as follows: "The result is a decrease in pain and discomfort, and improvement in circulation and so a hastening of repair. It also prevents much of the stiffness in joints and muscles, lessens the amount of atrophy and shortens the time for return of full power." Watson,[14] reporting on his experience with 400 cases of fracture treated by early massage and mobilization, stated: "Organization occurs during the first 9 to 10 days, hence it is during this crucial period that the local drainage apparatus—the circulatory and lymphatic systems—already reduced in efficiency by the injuries received, should be aided in their work of débris removal. Massage rapidly removes these effusions and extravasations by restoring the local lymphatic and circulatory drainage to its former efficiency." Murray [18] expressed himself thus: "It is today becoming recognized that physical therapy displays its chief and prime value in the early phase, in that stage when hemorrhage, exudate and transudate infiltrating the soft parts can be actually removed by painless physical therapeutic measures acting reflexly—not by direct pressure on the circulatory status of the part." Trethowan [19] said: "It is the acute case which benefits most from physical therapy and in which this expensive treatment is economically of most value. When treatment is unduly delayed, the efforts of the masseuse are devoted largely to combating the results of neglect—poor circulation, disuse atrophy, loss of power, stiff joints, contractures and adherent scars." Galland [20] wrote as follows: "The use of physical therapy must not be relegated to an attempt to rehabilitate cases

and edema, to restore normal circulatory conditions, to mobilize stiff joints, to free the scarred and contracted muscles and to build up their power is generally many times greater than the period required for the healing of the fracture. Physicians who are engaged only in private or hospital practice frequently fail to realize this, as most of their patients are dismissed at the time when further active treatment ceases to be necessary and generally before function has been completely regained. Industrial surgery has furnished a very useful check on the duration of disability, as under the industrial compensation laws the patients have to be followed and treated, not only until their fractures have healed, but until they are able to return to work. Since most of the patients are employed at jobs necessitating heavy labor, it is impossible for them to resume their occupations before they have obtained nearly complete functional recovery.

Studies of fractures among this group have shown that the disabling effects of the injury continued for a long period after the fracture itself had healed. The disability time of a fracture may be divided into two periods: the first, the period of consolidation, which extends from the moment of injury to the time when healing is sufficiently firm to permit the removal of fixative apparatus and the beginning of active use either with or without protection; and the second, the period of convalescence, which extends from the end of the consolidation period to the time when functional restoration is sufficiently complete to allow the resumption of normal activities or work. Figures obtained from the Industrial Accident Commission of Massachusetts [18] showed that the average duration of temporary total disability after fracture of the wrist was 9 weeks, whereas the period of consolidation was usually 3 to 4 weeks; and after fractures of the region of the shoulder it was 16.7 weeks against a consolidation period of 4 to 5 weeks. These figures were for all cases and included a large number of fractures of very minor nature, and in addition did not include the period of partial disability, which in industrial cases is often very long. End-result studies at the Massachusetts General Hospital showed that fractures of the bones of the lower leg rarely recovered before the end of 6 to 8 months, against a consolidation time of 10 to 12 weeks, and that fractures of the shaft of the femur usually caused disability of 10 to 12 months, whereas consolidation was usually complete in 8 to 10 weeks. The length of the convalescent period in relation to that of the consolidation period affords a rough measure of the effectiveness of functional treatment of a fracture. One would expect that a ratio of 2:1, that is, a convalescent period twice as long as the period of consolidation, would be a generous allowance in most cases, but actually under average treatment at present the ratio runs frequently 4:1, 5:1 and even higher. In the report of the Research Group of the Committee on Traumatic Surgery of the American College of Surgeons,[18] it was stated that out of a group of 863 fractures studied only 62.5 per cent made complete recovery. The average duration of disability

was 206.5 days. These figures assume even greater significance when it is pointed out that a very large percentage of these cases represented only fracture-sprains or fractures without deformity, and very minor fractures such as those of the fingers or toes. While it is doubtless true that other factors such as psychologic and economic considerations play a considerable part in determining the length of the convalescent period in industrial surgery, it is nevertheless evident that the period of disability after fractures is longer than it should be and that the results of treatment are still far from satisfactory.

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functionally impaired after long-continued surgical treatment of fractures, but must be included in our scheme of treatment from the earliest phase of handling the condition." The pioneer of physical therapy in fractures, Lucas-Championnière,[1] always emphasized that massage and mobilization should be used from the very beginning if the most striking results were to be obtained. His English disciple, Mennell,[3] has been equally convinced of this and described the effects as relief of pain and spasm, improvement in nutrition and earlier functional restoration.

Physical therapy must therefore be employed within the first two weeks of injury if any effect is to be obtained in the removal of hemorrhage and exudate. During the remainder of the period of consolidation, the chief function of physical therapy is in preserving the suppleness of the muscles, preventing adhesions, maintaining joint mobility, improving the circulation and, in general, counteracting the effects of immobilization. While physical therapy can be of great assistance in the early stage of fracture treatment, it must be pointed out that this is precisely the period when there is the greatest danger of displacing the bone fragments, and when the greatest harm is likely to result from undue motion at the seat of fracture. Treatment at this time cannot be entrusted to a technician with any safety, and if physical therapy is to be employed it will have to be administered either by the physician in person or directly under his supervision. Above all, the treatment must have the quality of painlessness, and if it cannot be administered without pain, it had better be abandoned. When the period of convalescence has been reached, and active use can be permitted, chief reliance must be placed in the patient's own efforts, and the rôle of physical therapy becomes chiefly educational, in showing the patient how to help himself by muscle reëducation and exercise. Physical therapy is valueless when long continued after the healing of the fracture, and there is little doubt that in this respect it has been subject to much abuse in the past. The Research Group of the Committee on Traumatic Surgery of the American College of Surgeons [14] reported that "a careful review of our statistical data justifies the opinion that the application of physiotherapy as now practiced generally does not warrant our approval, nor does it indicate that sufficient benefits are derived to justify its application indiscriminately, and when used it should be used early for a limited time."

Of the various agencies or modalities that are employed under the general designation of physical therapy, such as thermal stimulation, massage, movement, irradiation and electrical stimulation, only the first three are of established value in the treatment of fractures. In addition, the importance of elevation or postural treatment as an aid to physical therapy should be mentioned. Thermal stimulation includes heat and cold. The latter is used infrequently, but may be employed occasionally to check swelling under special conditions. Heat has the same action whether obtained by hot compresses, heating pads, radiant

lamps, diathermy or hot baths. It is soothing and relieves pain. It also brings about a vascular flushing of the part that may be of benefit as a preliminary to massage and movement. The use of heat is sometimes indicated in the early stage of fracture treatment to stimulate the circulation of an extremity when it is gravely embarrassed as the result of extensive injury and swelling.

Massage, of the light stroking variety described by Lucas-Championnière, is of great value in the early acute stage of a fracture and probably produces its effects reflexly through the nerves. It relieves pain and muscle spasm and has a direct effect in stimulating the circulation and overcoming vasomotor paralysis. In the later stage of fracture treatment, deep stroking massage and kneading, provided that they are painless, are useful for their mechanical action in getting rid of edema and improving nutrition. Movement is the complement of massage, and massage is almost a waste of time in the treatment of fractures unless supplemented by motion. In the early stage the movement should be of the passive type with the patient's muscles completely relaxed. Any active muscle contraction would cause movement at the seat of fracture and result in spasm and pain. Passive movement stimulates the circulation, prevents adhesions and contraction of the muscles, and maintains joint flexibility. In proportion as consolidation of the fracture proceeds, the character of the movement is changed from passive to active motion through the gradation of assisted movement. After union has become firm, chief reliance must be placed in active use and exercises performed by the patient. At this time occupational therapy offers a means of breaking the monotony of exercises by adding the interest and stimulus of performing a useful task.

Ultraviolet irradiation is not known to have any specific effect on fractures beyond its general action of stimulating calcium metabolism in the body. In conditions of disturbed calcium metabolism this action may be desirable, but its use should be reserved for this. Electricity in its various forms seems only to offer other means of obtaining the same effects as can be brought about by the use of heat, massage and movement. Diathermy has not been shown to have any specific action other than that of supplying heat centrally in the tissues. It is subject to great errors unless managed by a highly skilled person. A stimulating effect upon delayed consolidation has been claimed for it but has not yet been proved. The static brush provides the equivalent of light stroking massage. The various forms of electrical stimulation of muscle contraction by galvanic, faradic and sinusoidal currents undoubtedly may be of service under certain indications, but must be managed with great skill, and at best their use is likely to be dangerous. In addition, the machines are costly, not easily transportable to the patient's bedside and not infrequently produce unpleasant psychologic reactions, objections which seriously limit their use in the treatment of fractures. The Morton Smart [21] machine, which produces a completely controlled high-frequency current of a surging type, seems to be one of the best

for obtaining graduated muscle contraction and relaxation, but its place in fracture treatment at present is *sub judice*.

Physical therapy has always been subject to criticism because of the small body of scientific knowledge underlying the use of its various agencies, and because of its claims of therapeutic actions for which there existed no real proof. Unfortunately much of this criticism is justified. Mechanical development has temporarily outrun experimental study, with the result that a lot of different electrical machines have been produced for which every beneficial therapeutic effect is claimed that can be supported by enthusiasm or high-powered salesmanship. It is therefore important to differentiate between the agencies that are based on long clinical experience and observation and those that are not. Massage and mobilization, while lacking the complete scientific explanation of their mode of action that at present is desirable, have behind them a mass of clinical experiences which began in antiquity and which collectively constitutes valid evidence of their effectiveness. It is the same kind of evidence as that which led to the discovery and recognition of the therapeutic value of mercury and potassium iodide in syphilis, of quinine in malaria, or iron in anemia, and of cod liver oil in rickets many years before scientific data had been adduced to prove their value. The actions of the various agencies of physical therapy are susceptible of experimental investigation, and it is to be hoped that investigators will be stimulated to cultivate this rich but untilled soil. Until the results of such investigations are forthcoming, we will do well to confine our use of physical therapy, especially in the treatment of fractures, to those agencies which have stood the test of prolonged clinical experience.

The age of the patient has considerable bearing upon the need for physical therapy. In children not only does consolidation of the fracture occur more rapidly, but the effects of the traumatic reaction upon the soft parts are also more quickly overcome. The natural activity of children and their love of play quickly restores function, and it is more often necessary to hold them back than to push them forward. Consequently, physical therapy is unnecessary and usually but a waste of time in children below the age of fifteen years. Beyond this age the reactions to trauma are of the adult type, and physical therapy should be employed. Conditions for overcoming the effects of injury and restoring function become less favorable with increasing years until in old age they become definitely adverse. The less favorable the age of the tissues, the greater is the need for early physical therapy. The most fertile field for physical therapy in fractures is found in the middle-age period. Not only is this the period when bony injuries are common owing to the greater exposure to trauma, but it is also the period of active wage earning when the individual can least afford unnecessary loss of time. Functional disability must be shortened and permanent crippling avoided by the use of every therapeutic resource.

The type of fracture and its location are the most important factors

in determining whether or not physical therapy can be employed in the early stage. In the case of a loose displaced fracture, all depends upon the security of the reduction. Rather than to incur the risk of secondary displacement, it is better to postpone the use of physical therapy until consolidation is well advanced. Fractures of the shafts of long bones are particularly dangerous in this respect, and early massage and mobilization can be employed only in a limited way, chiefly after open reduction and internal fixation or in conjunction with skeletal traction and suspension. On the other hand, in the case of fractures of cancellous bone, conditions are much more favorable for the early use of massage and mobilization since there is much less risk of displacement, and union tends to occur rapidly on account of the abundant blood supply. Thus the most spectacular results are achieved in fractures of the lower end of the radius and the upper end of the humerus. In fractures of the lower end of the humerus, a good deal depends upon the individual type of fracture and its stability after reduction; some can be treated early and others cannot. Early physical therapy can be employed with great advantage in certain fractures of the knee and ankle, but subject to the limitations imposed by the individual case and the danger of losing the alignment. In fractures of the hip and wrist, especially of the carpal scaphoid, physical therapy is absolutely contraindicated except in the late stage because of the danger of nonunion.

Undisplaced Fractures

Fractures without displacement constitute a large and important group of injuries whose number is constantly growing larger as the practice spreads of making roentgenologic examinations in all cases of injury, irrespective of whether fracture is suspected or not. They include incomplete and fissured fractures, subperiosteal fractures, greenstick fractures, impacted fractures and many of the comminuted fractures in cancellous bone. Strictly speaking they are not altogether fractures without displacement, as deformity of greater or lesser degree may be present in certain impacted or greenstick fractures, but they represent cases in which the deformity is either not of a disabling character or in which, because of the nature of the fracture or the condition of the patient, there is more advantage in leaving the deformity than in attempting to correct it. The latter applies particularly to the comminuted fractures of the upper end of the humerus and to the impacted fractures of the neck of the femur in aged individuals. In the first, correction of the deformity necessitates fixation of the shoulder and results in stiffness, some of which may prove permanent; while, on the other hand, immediate treatment by massage and movement yields such good results even in the presence of considerable deformity that the latter plan may have the preference. In the case of impacted fractures of the hip—which are of rarer occurrence than

generally believed—correction of the deformity means breaking up the impaction and incurring the risk of nonunion, in addition to the disadvantages of prolonged treatment in a plaster spica. In comparison with this, the treatment of the impacted fracture is so much simpler and safer that the deformity must be great indeed to justify taking the risks of the alternative course. Lucas-Championnière [23] used to say that impaction represented the first stage of fracture repair already completed, and even went so far as to advise against disturbing it in Colles' fracture except in extreme instances. While I cannot subscribe to this extreme view, I do feel that there is every advantage in preserving impaction when there is no great deformity.

The treatment of undisplaced fractures affords a relatively simple problem, both because of the lack of necessity of reduction and the ease of maintaining alignment. When a fracture has withstood the primary trauma without displacement, there is little danger of secondary displacement, and all that is required in the way of fixation is light protective splinting of an easily removable type or traction-suspension to counteract the weight of the extremity. This group of fractures offers an ideal opportunity for treatment from the beginning by physical therapy. Superficial stroking massage and passive and assisted motion may be begun at once without the slightest danger. Rational use of these measures combined with rest and elevation will restore the circulation, maintain the suppleness of the muscles and the flexibility of the joints, and promote early recovery. It cannot be emphasized too strongly that complete and prolonged immobilization of such fractures represents a surgical crime.

Summary of Fracture Treatment

Rapid functional recovery from a fracture depends not upon emphasizing any one particular method of treatment, but upon attempting to apply in the proportions adapted to the needs of the individual case the three cardinal principles of fracture treatment: early reduction, maintenance of alignment and institution of therapeutic measures to promote the return of power and function. While wide latitude is permitted in the details of treatment, and different surgeons may adopt widely different methods to attain the same end, the principles underlying the treatment should remain the same. The goal of functional recovery should be constantly visualized, and the obstacles to be overcome in achieving this objective should be foreseen in each case and the treatment planned accordingly. Physical therapy represents only one means of attaining this goal, of value when it can be carried out in an ideal way, of secondary importance when other considerations are more imperious. The inability to employ physical therapy may be counterbalanced by attention to other details of treatment, and particularly by the use of every method that tends to

promote early activity and to shorten and render less continuous the period of immobilization.

The following represents a recapitulation of the more important points of treatment that have been mentioned in the preceding sections:

1. Splint all fractures at the place of the accident in order to prevent the additional pain, displacement and soft-part injury that will otherwise result during the transportation of the patient to the hospital or home.
2. Seek to obtain complete reduction of the fracture at the earliest possible moment after the injury by the use of that method, whether of the closed or open type, which offers the greatest chance of success with the avoidance of unnecessary and additional trauma by repeated efforts at reduction.
3. Try to splint the part in such a way that the greatest amount of use will be permitted without jeopardizing the position of the fragments.
4. Immobilize as few articulations as necessary to preserve the alignment and to provide favorable conditions for healing.
5. In so far as the requirements of the individual fracture permit, immobilize the joints in the positions most favorable for the rapid recovery of function. Thus the wrist should be fixed when possible in a position of dorsiflexion, the elbow in a position of flexion, and the ankle joint in a position of right-angle flexion. In these positions the action of gravity favors the return of motion, and any stiffness that may result will be less likely to cause disability.
6. Urge active motion and use of the adjacent and unimmobilized joints from the very beginning. Thus in the case of injuries of the upper extremities, the fingers and hand should be left free whenever possible and their use encouraged. When the shoulder joint is not fixed, regular exercises should be instituted to prevent contractures and loss of strength. In the case of the lower extremity, likewise, movement should be encouraged of all the unimmobilized joints, even if only of the toes. It should be remembered that the muscles activating these structures span considerable distances and often arise in the region of injury. Their contraction and use will be of great aid in getting rid of edema and exudate and in maintaining normal nutrition.
7. Avoid the dependent position, and employ elevation of the part whenever necessary in order to reduce swelling and provide local conditions as favorable as possible for normal circulation.
8. When it is necessary to apply rigid plaster-of-paris casings begin immediately to make plans for their removal at as early a period as possible to permit massage and mobilization. It will often be found possible to free a limb by cutting out a portion

generally believed—correction of the deformity means breaking up the impaction and incurring the risk of nonunion, in addition to the disadvantages of prolonged treatment in a plaster spica. In comparison with this, the treatment of the impacted fracture is so much simpler and safer that the deformity must be great indeed to justify taking the risks of the alternative course. Lucas-Championnière [13] used to say that impaction represented the first stage of fracture repair already completed, and even went so far as to advise against disturbing it in Colles' fracture except in extreme instances. While I cannot subscribe to this extreme view, I do feel that there is every advantage in preserving impaction when there is no great deformity.

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Technic of Physical Therapy in Fractures

Massage.—Of the various types of massage that have been described by different teachers and writers, there are only three that are of value in the treatment of fractures. These are superficial stroking, effleurage and kneading. The other forms of massage, such as friction, pétrissage and the different percussion movements or tapotement, are far too vigorous to be tolerated in a recent fracture and even in the convalescent stage accomplish nothing but harm. Indeed it has always been a criticism of massage as performed by the average technician in the treatment of injury that it is too strenuous and does harm rather than good. All too frequently it has been the aim to give the patient all he could stand, an objective inspired in part by the desire of the patient to be sure and get his money's worth, and in part by the lack of specific instructions as to what was wanted from the doctor. Vigorous massage of an injured part is given under a complete misapprehension of the goal that is sought, namely, to secure muscular relaxation and to benefit the circulation. Pain is always to be regarded as the warning signal, and massage that is painful is also harmful.

Early Massage of a Recent Fracture.—Massage of the peculiar superficial stroking type advocated by Lucas-Championnière [1] and his pupils is employed for the treatment of fresh fractures to relieve pain, secure muscular relaxation, overcome swelling and to benefit the circulation. As has been said before, it precedes and paves the way for mobilization. Its application is necessarily limited by the location and type of the fracture. To produce its full effects, the entire surface of the limb should be exposed to treatment. When dealing with loose, displaced fractures, this cannot be done without jeopardizing the reduced position of the fragment. Such fractures, if they are to be treated at all, must be treated over the small area that can be exposed by local adjustment of the splint. In some instances when the injured part is fixed by anteroposterior or lateral splints, one splint may be removed and the part supported on the other splint while the exposed surface is treated. This splint is then replaced, the position reversed and the other splint removed for treatment. The types of bony injury ideally suited for early massage and mobilization are the incomplete, impacted or undisplaced fractures. Because of the little tendency to displacement of such fractures, it is possible to remove the splints with safety and to support the part by cushions in a manner to permit complete treatment. In any case, regardless of the type of fracture, it is important that the part shall be completely supported in order to obtain the utmost of muscular relaxation before proceeding with the massage. Generally it is more difficult for a patient with a sensitive extremity to relax when sitting than when lying, and for this reason the recumbent position is usually to be preferred. The position of the joints should be semiflexed by the adjustment of pillows or cushions to insure the utmost comfort and relaxation.

of the plaster, as, for example, over the dorsum of the foot to permit a little movement of the ankle. When molded plaster or other splints are used, as in fractures of the lower end of the radius, or in the region of the elbow, make a point of removing the splints temporarily for massage and mobilization treatment, beginning a few days after injury.

9. When a fracture is treated by continuous traction, the extremity should be suspended and counterpoised in order to permit as much movement as possible of the proximal articulation while at the same time increasing the efficiency of the apparatus and promoting the patient's comfort. When skeletal traction is used, advantage should be taken of it to mobilize regularly, when possible, the joint distal to the point of insertion of the pin, wire or tongs. Thus, for example, in the case of a fracture of the shaft of the femur with traction by Kirschner's wire through the femoral condyles, it is often possible to begin partial mobilization of the knee joint within two weeks of the time of injury. In the cases of fractures of the upper end of the humerus that are treated in traction-suspension, it is often possible to suspend the forearm separately and to permit a little movement of the elbow and of the shoulder.

10. When the convalescent stage of treatment is reached, substitute light protective splints for completely immobilizing splints whenever possible, thus permitting a greater range of functional activities. In the case of the lower extremity, weight-bearing appliances, such as Thomas caliper braces or close-fitting plaster casings fitted with steel walking stirrups should be used whenever possible to counteract atrophy and stimulate the circulation.

11. Physical therapy, consisting mainly of light stroking massage and gentle passive motion, should be administered when possible without jeopardizing the position of the fragments, in the first two weeks of injury, to favor absorption of exudate and to improve the circulation. It should be continued regularly through the period of consolidation, changing gradually its character in proportion to the advance of callus formation. In the convalescent stage, active motion and use are of chief value, and the main function of physical therapy should be educational.

12. Fractures without displacement are subject to little risk of secondary displacement and require only light protective splinting of an easily removable type or traction and suspension. Massage and mobilization should be employed in practically all such fractures from the very beginning. Continuous and prolonged immobilization of such fractures causes as much disability as the injury itself and should be avoided at all costs.

Massage in the Later Treatment of Fracture.—Massage should never be more than of the light stroking type during the active phase of fracture treatment. Only when union is solid enough to permit the temporary or complete removal of the splint should any deeper pressure be permitted. Then deep stroking massage or effleurage supplemented occasionally by kneading may be employed for their mechanical effect in helping to drain the clogged lymphatics and to empty surplus fluid from the tissue spaces. Since its action is mechanical instead of reflex, effleurage should be administered only in the centripetal direction and always in the manner advocated by Wharton Hood [22] of beginning by massaging the tissues of the proximal portion of the extremity and emptying these, then proceeding a little distally and working back again over the proximal region, and repeating this maneuver as many times as necessary until the entire extremity has been treated. This procedure is based on the principle that the proximal lymphatic and venous circulation must be stimulated and the channels cleared before the fluid can be removed from the distal part with success.

While effleurage is classed as deep stroking massage and requires deep pressure, this does not mean hard or forcible pressure. The main requirement in order to administer effleurage properly is muscular relaxation. As long as the muscles are hard and contracted, even the most vigorous pressure would scarcely be able to produce any deep effect. On the other hand, with muscular relaxation the tissues transmit gentle, even pressure to the depths just as if they were a fluid medium. Light superficial stroking should always be employed to relax the muscles before proceeding with deep stroking, and even after this has been begun, when certain regions are found to be hard instead of soft, then one should return to the superficial stroking until these muscles have relaxed. Effleurage is intended to aid in the restoration of vasomotor tone and to assist in moving venous blood and lymph, thereby improving the nutrition of the tissues and promoting the elimination of waste products.

Massage of a kneading type may be used sometimes to supplement deep stroking movements when nontender fibrotic thickenings are encountered that do not respond to the latter. It is more often needed when dealing with an indurated scar in the muscles resulting from extensive soft tissue damage. It ought to be used only when complete union has been obtained, and never when its administration is attended by the slightest pain. There seems to be no place in fracture treatment for the use of the deeper movements of massage such as friction, pétrissage or any of the percussion movements such as tapotement, hacking, clapping, beating, vibrating or shaking. The value of these movements is debatable under almost any conditions, and they certainly have no place in the therapy of injuries.

Mobilization.—Nothing is so important as movement for restoring function after a fracture. It represents the very essence of *function*,

Superficial stroking is the only type of massage that should be employed in the early treatment of fractures. Its practice can only be perfected by actual experience. The movements must be slow, gentle and rhythmical, and made with the flat of the fingers, the hand being relaxed so as to adapt and mold itself to the part. The stroke should cover as large a part of the limb as possible, but should avoid the region immediately overlying the fracture until this ceases to be painful. In the case of the upper extremity the stroke should include the whole area from the hand to the shoulder, and in other regions it should be equally extensive. The contact with the skin should be so gentle that the patient scarcely feels the touch. Lucas-Championnière likened it to "little more than a caress." It should be performed in one direction only, and as it is employed chiefly for its reflex action, it matters little whether the direction is centrifugal or centripetal. The rhythm should be slow and even, and the same when the hand is returning through the air as when in contact with the skin. As lubricants I usually employ alcohol and talcum powder, but if the effect of these upon the skin becomes too drying it may be necessary to substitute olive oil.

The whole purpose of massage treatment in a recent fracture is to produce reflex effect, and the benefits that are obtained can scarcely be explained upon any other basis. The stroke is too light and gentle to have any mechanical action upon the edema and swelling. Furthermore, when the extent and degree of the swelling in a recent fracture are considered, it is evident that vascular dilatation or relaxation plays a large rôle in its causation. Vascular tone is maintained normally by the vasomotor nerves, and it is not unreasonable to suppose that in a state of vasomotor paralysis this nervous mechanism may be influenced by surface stimulation. Lucas-Championnière attributed the relief of pain in part to exhaustion of the sensory nerve ending by the repeated surface stroking, and this is as good an explanation of this part of its action as any that have been suggested. The benefits of the massage, when properly performed, manifest themselves by relief of pain and relaxation of muscle spasm. After relaxation has been obtained, then gentle movements of the passive type may be made. Even a small amount of motion in the beginning is beneficial, and later this can gradually be increased. It is always a matter for astonishment to witness the soothing effect of massage in a recently injured extremity, to see the muscles relax and movement be permitted that formerly was completely prohibited.

In the early stage of fracture treatment it is important not to tire the patient by too long treatment. The séances should be short, not exceeding fifteen to twenty minutes, and the treatments should be given daily or on alternate days. They should always begin and end with superficial stroking, mobilization of the joints being given between the two periods of massage.

MASSAGE IN THE LATER TREATMENT OF FRACTURE.—Massage should never be more than of the light stroking type during the active phase of fracture treatment. Only when union is solid enough to permit the temporary or complete removal of the splint should any deeper pressure be permitted. Then deep stroking massage or effleurage supplemented occasionally by kneading may be employed for their mechanical effect in helping to drain the clogged lymphatics and to empty surplus fluid from the tissue spaces. Since its action is mechanical instead of reflex, effleurage should be administered only in the centripetal direction and always in the manner advocated by Wharton Hood [33] of beginning by massaging the tissues of the proximal portion of the extremity and emptying these, then proceeding a little distally and working back again over the proximal region, and repeating this maneuver as many times as necessary until the entire extremity has been treated. This procedure is based on the principle that the proximal lymphatic and venous circulation must be stimulated and the channels cleared before the fluid can be removed from the distal part with success.

While effleurage is classed as deep stroking massage and requires deep pressure, this does not mean hard or forcible pressure. The main requirement in order to administer effleurage properly is muscular relaxation. As long as the muscles are hard and contracted, even the most vigorous pressure would scarcely be able to produce any deep effect. On the other hand, with muscular relaxation the tissues transmit gentle, even pressure to the depths just as if they were a fluid medium. Light superficial stroking should always be employed to relax the muscles before proceeding with deep stroking, and even after this has been begun, when certain regions are found to be hard instead of soft, then one should return to the superficial stroking until these muscles have relaxed. Effleurage is intended to aid in the restoration of vasomotor tone and to assist in moving venous blood and lymph, thereby improving the nutrition of the tissues and promoting the elimination of waste products.

Massage of a kneading type may be used sometimes to supplement deep stroking movements when nontender fibrotic thickenings are encountered that do not respond to the latter. It is more often needed when dealing with an indurated scar in the muscles resulting from extensive soft tissue damage. It ought to be used only when complete union has been obtained, and never when its administration is attended by the slightest pain. There seems to be no place in fracture treatment for the use of the deeper movements of massage such as friction, pétrissage or any of the percussion movements such as tapotement, hacking, clapping, beating, vibrating or shaking. The value of these movements is debatable under almost any conditions, and they certainly have no place in the therapy of injuries.

Mobilization.—Nothing is so important as movement for restoring function after a fracture. It represents the very essence of function,

Superficial stroking is the only type of massage that should be employed in the early treatment of fractures. Its practice can only be perfected by actual experience. The movements must be slow, gentle and rhythmical, and made with the flat of the fingers, the hand being relaxed so as to adapt and mold itself to the part. The stroke should cover as large a part of the limb as possible, but should avoid the region immediately overlying the fracture until this ceases to be painful. In the case of the upper extremity the stroke should include the whole area from the hand to the shoulder, and in other regions it should be equally extensive. The contact with the skin should be so gentle that the patient scarcely feels the touch. Lucas-Championnière likened it to "little more than a caress." It should be performed in one direction only, and as it is employed chiefly for its reflex action, it matters little whether the direction is centrifugal or centripetal. The rhythm should be slow and even, and the same when the hand is returning through the air as when in contact with the skin. As lubricants I usually employ alcohol and talcum powder, but if the effect of these upon the skin becomes too drying it may be necessary to substitute olive oil.

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fracture instead of at the articulation; that it serves as an excuse for physicians to manipulate joints violently in pump-handle fashion, of which the harmful results have been frequently seen; and that the goal that is aimed at by passive motion can be obtained with much greater benefit to the patient from the use of active motion. Such criticisms are made without knowledge of what passive movement is or of what it is intended to accomplish. I do not dispute the greater value of active movements when they can be performed, but I know that passive motion can be employed in patients with fractures when active motion would only be harmful. Passive motion is not advocated as a substitute for active movement, but only with the aim of getting movement started as early as possible, and of employing it to lead up to active movement just as massage leads up to passive motion. The criticism that passive motion is resisted by the patient's muscles is made without proper understanding of the fact that passive motion is employed only with the patient's muscles completely relaxed. Passive motion that is resisted by the patient is no longer passive motion, but resisted movement; and the physiotherapist who cannot distinguish between these two types of movement is not worthy of the name. Mr. Mennell of London [3] has suggested that the name *relaxed motion* be substituted for the term *passive motion* in order to promote better understanding of what it really is, and this change appears advantageous. Passive motion is undoubtedly subject to abuse just as are most procedures of medicine and surgery, but the remedy is proper instruction rather than complete abandonment of the method.

Relaxed Motion.—Relaxed motion is employed in the treatment of fractures as the first effort at mobilization. In certain types of fractures that are attended by little danger of displacement of the fragments, it may be employed in conjunction with light stroking massage beginning immediately after injury. In other cases where the risk of displacement is greater, its use must be postponed until consolidation is sufficiently advanced to obviate this risk. It may be used frequently at an early period in conjunction with the traction-suspension treatment of fractures. As has been explained previously, it requires complete muscular relaxation on the part of the patient, and this is best induced by a preliminary treatment of light stroking massage lasting from ten to fifteen minutes. Relaxation can only be obtained when all of the preliminary treatment leading up to mobilization, including the removal of the splint, the handling of the limb and the massage, has been characterized by extreme gentleness. Never even for a moment should there be the slightest interruption of the physical therapist's constant vigilance to avoid pain. The slightest sensation of pain will cause the patient's muscles to tighten and defeat the purpose of the treatment.

The treatment should be given with the patient sitting or recumbent, and with the part arranged in a position which permits relaxation and allows the physiotherapist to reach it in the most convenient

and to gain motion is the goal of all forms of physical therapy. Mobilization is the *raison d'être* of massage in the treatment of injuries of bone, and massage without movement is almost a waste of time. "Movement is life" was the maxim of Aristotle quoted by Lucas-Championnière, and in the case of an injured extremity there is no doubt that movement is the means of restoring life. It stimulates the circulation, aids in the absorption of edema and other products of inflammation, restores the flexibility of the joints, frees the muscles from adhesions, overcomes atrophy and restores strength. Determination and persistence on the part of the patient in moving the joints that have been immobilized will restore function after the majority of fractures, even in the absence of medical supervision. This, however, is the harder and longer way, and few individuals possess the necessary fortitude or can afford the loss of time necessitated by the slower method of progress. In order to obtain the best results, movement should be employed scientifically from the very beginning and with due regard for the pathologic physiology of the injured structures, and when used in this way it affords the means of shortening the period of convalescence and of improving the functional result.

A great deal could be written on the subject of movement, but this has been considered in detail elsewhere in this work, and our purpose is merely to review the different forms of movement in relation to the treatment of fractures. Movement may be divided into two classes—active and passive. Under passive motion are to be considered relaxed motion and forced motion. Under active motion are included the subdivisions, muscle setting, free motion, assisted motion and resistive exercises.

Passive Motion.—Before considering the use of passive motion, it will first be necessary to define what is meant by this term. Passive movement is motion that is performed without either active help or resistance from the patient's muscles. It requires mental coöperation on the part of the patient in securing complete muscular relaxation. To obtain this coöperation, in the case of a patient with a fractured extremity, is an art that requires the maximum of patience and gentleness on the part of the physical therapist. It is here that gentle stroking massage has an important rôle in preparing the way and obtaining relaxation. Extreme gentleness is the *sine qua non* of success. The slightest jar or sudden movement will cause the patient's muscles to tighten, and harmful resistive motion will be substituted for beneficial, passive movement.

It is this feature that accounts for the ill repute that has at times attached to passive motion. There are a number of surgeons who can see nothing but danger in the use of passive motion and who would abandon it altogether for active, voluntary motion. They claim that even at its best, it is likely to provoke resistance from the patient's muscles and cause movement to take place at the seat of

fracture instead of at the articulation; that it serves as an excuse for physicians to manipulate joints violently in pump-handle fashion, of which the harmful results have been frequently seen; and that the goal that is aimed at by passive motion can be obtained with much greater benefit to the patient from the use of active motion. Such criticisms are made without knowledge of what passive movement is or of what it is intended to accomplish. I do not dispute the greater value of active movements when they can be performed, but I know that passive motion can be employed in patients with fractures when active motion would only be harmful. Passive motion is not advocated as a substitute for active movement, but only with the aim of getting movement started as early as possible, and of employing it to lead up to active movement just as massage leads up to passive motion. The criticism that passive motion is resisted by the patient's muscles is made without proper understanding of the fact that passive motion is employed only with the patient's muscles completely relaxed. Passive motion that is resisted by the patient is no longer passive motion, but resisted movement; and the physiotherapist who cannot distinguish between these two types of movement is not worthy of the name. Mr. Mennell of London [3] has suggested that the name *relaxed motion* be substituted for the term *passive motion* in order to promote better understanding of what it really is, and this change appears advantageous. Passive motion is undoubtedly subject to abuse just as are most procedures of medicine and surgery, but the remedy is proper instruction rather than complete abandonment of the method.

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manner and to work at the utmost mechanical advantage. The patient must at all times have a feeling of complete security. The amount of motion to be administered is to be determined only by actual experiment. "Little but often" is the best principle. In the beginning the amplitude of the movement is less important than the fact that some movement is made. Even a little motion helps the circulation, promotes the absorption of exudate and keeps the joints supple. As the treatment proceeds, the range of movement can gradually be increased. The physical therapist's finger tips must be sensitive to detect the slightest sign of muscular resistance, and this is to be interpreted as the sign that the range of motion is exceeding the therapeutic limit. Preferably the motion should be performed with the joint semiflexed and with the neighboring joints in the positions that favor the freest motion, as, for example, dorsiflexion of the wrist for flexion and extension of the fingers, flexion of the elbow for supination of the forearm, flexion of the knee for dorsiflexion of the ankle, etc. Until healing is well advanced, the arc of relaxed movement should never exceed 50 to 60 per cent of the normal range of joint motion.

The whole purpose of relaxed motion is to get movement started when it cannot be performed in any other way. As consolidation of the fracture progresses, relaxed motion should shade off into one of the forms of assisted movement, and finally through this gradation to active exercise performed entirely by the patient. As soon as movement that could at first only be performed passively can be done by active contraction of the patient's own muscles, no further reason exists for the use of passive motion, and this should be stopped.

The movement should be made with the physical therapist supporting the region of the fracture with one hand while supporting the weight of the limb with the other. All of the joints of the injured extremity should be moved in every direction of which they are capable. In addition, the mobilization should extend to certain movements which are not a part of the regular joint motions although necessary to good function, such as lateral mobilization of the patella on the trochlea, which frees and relaxes the lateral expansions of the capsule and quadriceps muscle, and mobilization of the heads of the metatarsals or metacarpals both individually and in relation to each other, which maintains and restores the normal flexibility of the plantar and palmar arches.

Forced Motion.—The only purpose of mentioning the forcible variety of passive motion is to warn against its use for the treatment of fractures. To be of the truly passive type, forced motion must be performed with the patient completely anesthetized in order to obtain muscular relaxation. This is a dangerous procedure, as the pain reflex is abolished and the operator lacks that warning signal to indicate when structures are being injured. If forcible motion is made with the patient awake, it is resisted by his muscles and quickly degenerates into a strength test between patient and doctor, from which the latter

is likely to emerge the victor at the cost of considerable damage to the patient. Manipulators and bone setters have developed a certain skill in performing sudden forcible movements when the patient's muscles are off guard, but such manipulations are but rarely indicated after fractures and expose the patient to more risk than gain.

The only purpose of forced movements is to break up adhesions between muscles or to stretch a contracted joint capsule, and such conditions are best overcome by active and assisted exercises. The use of forcible manipulation after fractures is very likely to result in refracture or, failing this, may lead to the rupture of soft tissues with hemorrhage and the later development of an ossifying hematoma or ossifying myositis, examples of which have been seen all too frequently in the regions of the elbow. Under the best of circumstances, forced movements cause tissue damage with resulting pathologic changes that delay recovery and prevent the gain of motion, thus defeating the very end that is being sought.

Active Mobilization.—Active motion may be subdivided into four classes or groups: muscle setting, free motion, assisted motion, resisted motion.

Muscle Setting.—Muscle setting is a muscle exercise rather than a motion, as it is not intended that it should be accompanied by any joint movement. It consists in teaching the patient actively to contract or tense certain muscles or muscle groups without producing movement. This produces an effect in maintaining the circulation and nervous control of the muscles and of counteracting atrophy. This exercise is of great value in the treatment of fractures, and since there is no accompanying movement, it may be performed from a very early period after injury, and even when the part is completely immobilized by splints. As the exercise takes very little time and is not attended by pain, it may be performed from 75 to 100 times a day divided in two or three sessions.

Muscle setting is of the greatest valne in maintaining the tone and suppleness of the quadriceps extensor muscles of the thigh, in the case of fractures involving the lower extremity. This muscle group deteriorates rapidly with immobilization, and as it plays a vital rôle in controlling and stabilizing the knee joint, maintenance of its function is of great importance. When quadriceps-muscle setting has been employed systematically after a fracture of the lower extremity, the muscle recovers its strength and extensibility more quickly, and the function of the knee joint is also better. Muscle-setting exercises may likewise be employed in the case of the deltoid muscle, the flexor muscles of the elbow and the extensors of the foot. If the leg is incased in plaster, the action of the extensor muscles can be much augmented by cutting out the portion of the splint covering the dorsum of the foot and ankle so as to permit a little ankle movement. Some individuals are much quicker than others in learning the trick of muscle setting, and much

patience and persistence may be required before satisfactory performance of the exercise is obtained. The patient should be taught by first using the muscles of the uninjured side for demonstration purposes, and only when satisfactory control has been acquired here should he be permitted to proceed with the exercise on the injured side. The normal muscle thus always serves as a check or means of comparison which the patient may use if any doubt exists as to whether he is performing the exercise properly.

FREE MOVEMENT.—One of the fundamental rules of any program of muscle training or reëducation is to avoid fatigue of weak muscles. When muscles have been weakened by injury and long fixation, as in the case of patients with fractures, it is of the utmost importance to see that they are not required to do too much work when active exercises are first started. Overloading of the muscle must be avoided, for either the muscle will become stretched and not respond satisfactorily, or else it will quickly become fatigued, and in either case no real progress will be made toward building up its strength. For every movement there are always at least two antagonistic sets of muscles to be exercised, namely, the flexors and the extensors, and it is important to plan the exercises so that each group gets its fair share of work. Otherwise gravity conspires to assist one of the movements and to resist the other, with the result that one set of muscles does insufficient work, while the other set does too much work.

Free motion is planned to overcome this difficulty. It is movement that is performed entirely by the patient's own muscles without assistance or resistance in either flexion or extension. The influence of gravity upon the movement is eliminated as completely as possible by supporting the part on a smooth hard surface in such a position that both flexion and extension are performed in a plane horizontal to tho earth's surface. Thus free flexion and extension of the elbow may be carried out with the patient sitting and the arm supported at shoulder level on a smooth flat surface such as the top of a table. Both the forearm and upper arm should rest in contact with the surface during all stages of the movements. Or these exercises may be given with the patient lying on the uninjured side and the elbow and forearm resting on the side of the chest. Free abduction and adduction of the shoulder are best performed with the patient recumbent on his back, the elbow flexed acutely and the upper arm resting on its posterior surface on a wide board with a polished surface. The advantages of free motion are exemplified in this movement particularly. Patients who are totally unable to abduct the shoulder when standing, which necessitates overcoming the force of gravity, can often perform this movement quite well when recumbent. Free motion of flexion and extension of the fingers and wrist may be performed with the patient sitting and the hand resting on its ulnar border on the top of a table.

Free movements of the lower extremity are performed in a similar

manner, usually with the patient lying. In the case of the ankle, free movement may be obtained with the patient recumbent on his side and the lower leg and foot supported by a smoothly polished board on either the medial or lateral surfaces. Flexion and extension of the knee can be performed with the patient in the same position but with a broad board inserted between the legs, the injured extremity resting on its medial surface. Free motion of the hip in abduction and adduction is possible with the patient lying in a dorsal recumbent position. The nearest approximation to free motion of flexion and extension of the hip is obtained with the supporting board between the legs, shifted as high as possible into the perineum, and the patient lying on the uninjured side.

Free motion has a definite place in the treatment of fractures. It is chiefly indicated when the transition from passive to active movements is being made, at the time when healing has progressed to the point of consolidation but when the callus is still soft and requires protection. The callus should not be subjected to the strain of bearing the unsupported weight of the distal part of the extremity, nor is the muscular strength sufficient as yet to perform this amount of work. Free motion provides support for both segments of the limb, protects the fracture, reduces the amount of work to be done by the muscles and at the same time permits active, voluntary movement. The technic of free motion is individual and fussy, however, and is not likely to be used by any except very skilled physical therapists. Practically speaking, exercises performed in the recumbent position accomplish the purpose of free motion, especially when supplemented by a little assisted movement, the weight of the extremity being supported by the physical therapist.

Assisted Movement.—Assisted movement is the name used to designate motion that is performed by active contraction of the patient's own muscles, but with outside assistance of one kind or another. The assistance given may vary, on the one hand, from gentle support of the weight of the limb by the physical therapist, with the purpose of producing an effect similar to that of free motion, to, on the other hand, the application of a considerable amount of force in trying to supplement and reënforce the patient's own muscles in forcing a motion to overcome a contracture or to stretch fibrous adhesions. There is, of course, a great variation between these two extremes in the amount of force used, and any intermediate degree of assistance may be given as well. There is one common characteristic, however, to all degrees and types of assisted motion, namely, that the movement is always performed with the assistance of the patient's own muscular efforts; never against it. This distinction is of fundamental significance. If the patient's muscles oppose instead of assist the movement, then it is no longer assisted but resisted motion, and nothing but harm can result. Resistance is likely to be encountered

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when a very considerable amplitude of movement is present in the joint which is both free and painless. The second method of employing resisted movement may be used at a much earlier stage in the treatment of a fracture, at the time when union is becoming firm and it is desired to begin active contraction of the patient's muscles. It utilizes the principle that it is easier for a patient to contract a muscle and resist movement than it is actually to perform the movement. It takes advantage of the reflex mechanism controlling the action of antagonistic muscle groups when motion is performed. The opposing muscle contracts only to play out slack as the movement progresses. This type of resisted motion helps to reëducate the patient's muscle sense and to reëstablish voluntary muscular control which has been lost as the result of injury or of prolonged disuse.

Resisted exercises may also be given very usefully with the aid of apparatus, the purpose here being to increase the amount of work done by certain muscles. While the distinction between assisted and resisted motion is a fundamental one and needs to be maintained, it breaks down and becomes of little practical importance when apparatus is employed. Thus, a patient who practices flexion and extension of the elbow with the aid of a pulley exerciser performs resisted movements in flexion and assisted movements in extension. Similarly, when he exercises with a dumb-bell or Indian club, he does resisted work when raising the club in the air, and assisted work when the club is descending in the return motion. Riding on a stationary bicycle involves both resistive and assistive exercise. Actually, this makes little difference in the late stages of fracture treatment so long as the fact is recognized and steps are taken to reverse the position and insure that the muscles that previously had assisted movement are now given resisted movement, while assistance is given to the muscles that previously worked against resistance.

The Application of Heat.—The application of heat is useful in the treatment of fractures under certain conditions, but almost always in conjunction with massage and mobilization; alone it has little therapeutic effect. The rationale of the use of heat in any of its forms is the temporary production of a vascular dilatation in the part and a more rapid and abundant circulation of blood. In addition, heat has a definite soothing effect upon pain, the mechanism of which is not clear. The vascular changes resulting from the application of heat are probably more superficial than deep and also too transient to be able to influence the reparative process or to benefit fracture healing. On the other hand, the vasodilatation lasts long enough to permit massage and mobilization to profit from the greater vascularity in improving tissue nutrition and getting rid of the accumulated waste products of metabolism. The soothing and relaxing effects of heat are also beneficial as a preliminary to massage and mobilization, and their value has been established by clinical experience.

only when the joint is sensitive and the movement painful, and movement should never be forced under such circumstances. Here, just as in the case of relaxed motion, thorough preparation is necessary, by means of gentle massage to obtain muscular relaxation, and by a faultless technic on the part of the physical therapist in handling the limb so as to avoid pain, which inspires confidence in the patient.

Assisted motion may be given by the manual aid of the physical therapist, or apparatus may be employed such as the cord, weight and pulley, a rod or dumb-bells. Assisted motion offers great play for the inventive power of the physical therapist. A variety of procedures may be devised to accomplish a given purpose, and these have to be adapted to the needs and psychology of the patient. Benefit often results from teaching the patient to assist and reënforce his own muscular movement. Thus he may assist supination of an injured forearm by rotating the wrist with the other hand; he may aid flexion of the hip by lying on his back, clasping his flexed knee with both arms and hugging the hip into extreme flexion; he may aid abduction of the shoulder by grasping the ends of a wooden rod with both hands, the arms being by the side, and, by a movement of adduction of the uninjured shoulder, push the injured arm in the lateral plane away from the body, and he may use the body weight to assist in flexing the knee by standing, holding on to the back of a chair, bending the knees and squatting down as far as possible on the heels. In general, apparatus is of use only in direct proportion to the intelligence and determination of the patient, and it is preferable whenever possible to devise methods of play or of work that will accomplish the same end and be more valuable because of the added element of interest. The latter method has the further advantage of teaching the patient to rely upon his own efforts and of stimulating his own initiative.

Gentle assisted motion is given in the early stage of fracture treatment in order to enable the patient to accomplish more than he could otherwise do by his own efforts. In the late stages of fracture treatment, strong assisted motion may be employed to overcome muscle contractures and scar adhesions in order to increase the amplitude of movement.

Resisted Movement.—Resisted exercises are intended to build up strength in weak muscles by increasing the amount of work to be done. They may be performed in one of two ways: either by requiring the patient to perform a movement which is resisted manually by the physical therapist, or by the physical therapist making the joint perform a movement which is resisted by the patient. The first method is to be employed only in the late stages of fracture treatment, when dealing with muscles whose strength is already so far developed that they should be required to do more work than that represented by lifting the weight of the extremity and overcoming gravity. It should only be used when there is no longer any danger of refracture and

during the period of sensitiveness and should be discontinued when function begins to return and active use is possible, or at a much earlier period if the patient does not seem to be making sufficient effort on his own part for progress.

Continuous baking at a low heat is occasionally indicated in the treatment of fresh fractures when the circulation of the extremity is imperiled by vascular injury. The vasodilatation may enable enough additional blood supply to get through to maintain viability, pending the establishment of an adequate collateral circulation.

Hot Baths.—The warm whirlpool bath is the only form of hot bath that should be used by the physical therapist in the treatment of fractures. Its effects are obtained by the combination of heat and gentle superficial massage, the latter being provided by the whirling currents. Such baths are stimulating to the circulation and are useful in improving nutrition and, when combined with active exercises performed while in the bath, help in overcoming stiffness and in restoring function after fractures involving the distal portions of the extremities. Obviously they are only indicated when union is sufficiently solid to permit the removal of all splints with safety.

The hot bath or soak is a form of home therapy that is frequently prescribed for the general purpose of overcoming sensitiveness and encouraging the patient to move the part. Danger lies in the fact that it is often overdone, and the prolonged soaking with the part dependent favors the accumulation of edema. Contrast bathing with alternate soaking in hot water for one to two minutes followed by rapid immersion under cold, running water is a much more valuable form of home therapy, useful because, in the words of Sir Robert Jones,[23] it provides an exercise for the blood vessels of alternating vasodilatation and vasoconstriction and thus stimulates better vasomotor tone and counteracts any tendency for the accumulation of edema. Neither the hot nor the contrast bath should be given by the physical therapist, as both can be done with equal effectiveness and much greater economy at home.

Diathermy.—Diathermy has never been shown to have any specific action beyond that of producing heat centrally in the tissues. Its soothing effect upon pain is therefore to be explained as the action of heat. In contrast, however, with external heat that penetrates only superficially, diathermy may at least in theory be focused so as to produce heat at any depth in the tissues. Thus it is possible to generate heat in the region of the fracture, and it appears plausible that the resulting hyperemia in and about the callus may be favorable to the deposition of calcium salts and hasten consolidation when it is being delayed by other than mechanical causes. Granger[24] has reported good results from the use of diathermy in delayed union, but his conclusions were based on the clinical observation of only a small

The use of heat, however, has been subjected to greater abuse probably than that of any other agency of physical therapy. To turn on a radiant heat lamp or an electric baker is easy and keeps the patient occupied, and the period of rest and relaxation under the soothing heat rays is the part of the treatment that the patient enjoys the most. If any part of the treatment is to be discontinued, he will willingly forego the part of the program that involves actual work but will want to retain the use of heat until the last. In consequence it often happens that heat treatments are continued for long periods after they have ceased to be beneficial and often at the expense of active mobilization, the patient being lulled into a state of false contentment based upon the supposition that the treatment he is receiving will be the means of restoring function without any active effort on his part.

Not only may the use of heat be harmful in placing emphasis upon the least beneficial part of the treatment, but its prolonged use may be actually injurious to the tissues and result in pathologic instead of physiologic effect. Examples of the latter are unfortunately encountered all too frequently. The appearance of a part that has been exposed to too much heat is characteristic, and the entire story is revealed at the first glance. The skin of the region that has been treated is mottled and irregularly pigmented. The superficial tissues are hard and indurated to the touch. If the area is part of an extremity, the distal portion is usually edematous and boggy. I have had occasion to make incisions through such areas and have found the skin leathery and greatly thickened, and the underlying tissues avascular and fibrosed. The prolonged use of heat, therefore, defeats its own object and hinders recovery of function. It should be used only for a definite purpose and over a short period; when that purpose has been attained, it should be discontinued. It should never be employed in conditions of nerve injury when there is the slightest disturbance of cutaneous sensibility. In such cases, burns are likely to occur in spite of the greatest care, and the only safe rule is not to use it at all.

Heat may be employed in different ways for the treatment of fractures, but the more important are radiant heat, hot baths and diathermy.

Radiant Heat.—The most convenient and generally used method of applying heat in the treatment of fractures is the electric radiant heat baker. The single radiant heat lamp is much less effective and more time-consuming. Electric baking is indicated in the early convalescent stage of fracture treatment as a preliminary to massage and mobilization. All splints should be removed, the part placed in a comfortable position securely supported by pillows and sand bags as necessary, and the heat turned on to a low degree of intensity. The duration of the treatment should not exceed fifteen to twenty minutes, and, as a rule, it should not be repeated more frequently than on alternate days. Electric baking should be employed only

on the lookout for unexpected developments. Any unfavorable sign should be reported immediately.

The surgeon should personally administer such physical therapy as is indicated in the early stage of fracture treatment. As long as there is danger of displacement of the fragments, and careful handling of the part and skillful management of the splints are required, it is obviously unwise to delegate the treatment to a technician. It is only when the consolidation of the fracture is sufficiently advanced to reduce the risk of displacement and of other complications to the minimum that the services of the assistant may be employed. The surgeon should continue to see the patient as frequently as necessary in order to observe the effects of the treatment, to make such changes in the treatment as are from time to time indicated and to see that the patient is receiving adequate benefit from the treatment. Frequent consultations between the physical therapeutic technician and the doctor, with the patient present, are necessary to avoid misunderstandings and insure progress.

A great deal of responsibility devolves upon the technician in treating fractures. She must always bear in mind that the treatment is fraught with danger and that excess of zeal may result in harm. She should keep a careful record of progress in each case, measuring and recording the range of motion with the arthrometer. Impressions of the range of motion are always unreliable. Accurate records of the arcs of motion are of great importance, not only in showing whether or not treatment is beneficial and progress is being made, but also in encouraging the patient and in giving him confidence that his treatment is being properly controlled. The technician must also remember that while she has certain technical duties to perform as an operator, her chief function should always be that of a teacher. It should be her objective to educate the patient to an understanding of the relative importance of what is done for him and of what he does for himself, and of the greater value of the latter. When the proper moment arrives she must emphasize the importance of active use and encourage it in every way. She should follow a consistent policy of not helping the patient any more than is absolutely necessary, as, for example, in seeing that the patient removes and puts on his clothing without assistance. The performance of little tasks in connection with the toilet, the meals or certain household duties should be encouraged. At the same time the kind of physical treatment given the patient should reflect the gain in functional ability and should contain a large amount of active, voluntary work.

While active use of the part is the goal, it must be remembered that this is dangerous at an early stage because it cannot be graduated or controlled. The principle of treatment that should always be followed in building up strength in weak muscles is to keep the amount of work done below the fatigue point. When a weak muscle is required to do too much work or becomes overstretched, it is likely to play out for a

group of treated cases, and it is difficult to prove that this was the factor that accomplished the result instead of other factors that were likewise concerned. The action of diathermy in stimulating consolidation of a fracture must be regarded as distinctly *sub judice* until additional evidence has been obtained. In the meantime, if the effect of diathermy is to be tried in cases of delayed union, it will be advisable to limit its use to those fractures where no mechanical causes exist to account for the retarded healing, such as interposition of tissue between the fragments or lack of proper reduction, and also to use it not later than three to four months after the injury. Beyond this period the local situation in respect to callus formation has become so static that it is impossible to see how heat or hyperemia would be of any assistance. Immobilization of the fracture should not be discontinued during the period of treatment by diathermy, even though the presence of the splints interferes somewhat with the most efficient localization of the effect at the desired point. Granger solved this problem by cutting out windows in the plaster casings on opposite sides at the level of the fracture and applied the electrodes here. In other cases, one electrode was placed on the extremity proximal to the cast or splint, while the other was placed directly over the fracture. The treatments should not be given more frequently than on alternate days, and the duration should be about twenty minutes. If any effect is to be obtained from diathermy it should become manifest in four to six weeks, and there seems to be no reason to prolong the treatment over a period of more than one month.

Aside from its purely experimental use in delayed union, the writer is unable to find any other condition in fractures where diathermy is indicated which cannot be treated just as well, if not better, by the application of external heat in one or another form. In fact, a more extensive and superficial type of heat effect is to be desired as a preliminary to massage and mobilization than the deep localized heat effect of diathermy.

The Technician and Muscle Reëducation with Reference to Fracture Treatment

The administration of physical treatment for fractures is time-consuming, hence if it is to be employed efficiently and economically, resort must be had at certain times to the aid of trained technicians. To secure proper treatment requires the closest coöperation between the surgeon and the physical therapeutic technician. They are the two parts of a team, and the more harmonious the teamwork, the greater the benefit to the patient. Both have their own particular spheres, but each can reënforce the other's efforts. The surgeon is in charge and must assume the responsibility of directing the treatment. The technician's chief task is to carry out the doctor's orders, but at the same time she should carefully observe the patient's reactions and be

has reached the maximum of improvement, but should be taken much earlier at the time when the patient has developed enough motion and confidence to really go ahead and use the part. From this point, improvement is chiefly a matter of time with an occasional check-up and encouragement by the physician.

The Treatment of Fractures in Specific Regions

FRACTURES OF THE UPPER EXTREMITY

Analysis of the function of the upper extremity shows that it is specialized and quite different from that of the lower extremity. Freedom of movement and well coördinated muscular activity are the chief requirements. While powerful muscular contractions may be required in the performance of many tasks, such efforts are rarely long sustained, and the characteristic activity is intermittent with alternating periods of work and rest. This is in marked contrast with the function of the legs, where the task of bearing the body weight in standing and walking necessitates prolonged effort. Likewise the arms are used chiefly in lifting, pulling, pushing or twisting, and the strain is one of leverage instead of end-thrust as in the case of the legs.

All function of the upper extremity centers about and is subservient to that of the hand. The hand is the tool, and the forearm and upper arm, together with the various articulations, are merely the levers and gears that adapt the tool to its tasks and apply the power, and provide the means of movement. The usefulness of the upper extremity depends upon maintaining the delicate and multiple activities of the fingers and thumb. If these are lost, the result is almost as unfortunate as if the extremity were amputated.

The treatment of fractures of the upper extremity must therefore be directed with the constant consideration of the necessity of preserving the mobility of the articulations and the suppleness of the muscles. In case of conflicting indications in the treatment of a patient, one should usually adopt the course that favors the retention of the greater amount of movement even if it is at the cost of a slight sacrifice of alignment. Alteration of bony alignment in the upper extremity, while undesirable and unesthetic, has little functional significance unless because of proximity to or involvement of a joint it causes limitation of motion. Angular deformity does not have the same repercussions upon the articulations as in the case of the legs where, due to the weight-bearing function, it almost always results in joint strain and irritation. But above all, the motions and control of the fingers and thumb must be preserved.

Because of the need of preserving movement and control, physical therapy is called upon to play a prominent part in the treatment of fractures of the upper extremity. Early massage and mobilization may be employed by the surgeon under almost ideal conditions in many of

considerable period of time. Hence, a weak muscle should always be employed in a partially shortened position, and the amplitude of the movement should be increased only proportionately with the gain in power of the muscle. Herein lies the danger of uncontrolled active use of a part at a time when the muscles are still weak from injury and lack of use. The patients fail to progress and complain of pain, and examination shows a decrease rather than a gain in movement. The remedy here is to rest the muscle, not to exercise it more.

All of the various types of motion that have been previously described blend into each other more or less so far as their use is concerned. There is no one moment when one should change from passive to assisted motion, or from the latter to resisted movement or to active use. On the contrary, the use of the different kinds of motion should overlap and the transition from one kind to the other be made gradually. In general, one should begin with muscle setting and a little passive motion as early as possible. As soon as the consolidation of the fracture permits, the passive movements should be supplemented by a little gentle assisted motion or free motion. A short session of resisted exercise, with the patient resisting and the physical therapist making the movement, will aid in establishing the control of the muscles and prepare the way for gentle assisted movements. As quickly as possible, active exercises with and against gravity should be added and the frequency and amplitude of the movements increased. Finally, when active use of the part has been permitted, resisted exercises should be employed with the patient performing the movement resisted by the physical therapist, and forced assisted movements should be added to attain the last degrees of joint motion.

When the stage of treatment has been reached when all splints and apparatus have been discarded, the general purpose of the treatment should be to show the patient exercises that he is to perform at home systematically, and to reserve the balance of the session for doing things that the patient cannot do as well by himself. Active exercises can often be done better if performed simultaneously with both extremities, and, for this reason, many of them should be performed, using both sides. Means of using the injured part should be suggested to the patient. For example, in the case of the upper extremity, dishwashing, sweeping, writing, sewing, typing or driving a motor car may be advised. For the lower extremity, walking, gardening and working the pedal of a sewing machine, jig saw or bicycle provide valuable exercise. Games may be suggested, such as golf, swimming, or playing various musical instruments that will exercise the part.

In the early stages of fracture treatment, physical therapy should be employed at fairly frequent intervals. Treatments given every other day are usually fully as satisfactory and obtain as rapid progress as daily treatments. As strength and movement improve, the sessions should be dropped down to twice a week, then once a week and finally discontinued. This latter action should not be delayed until the patient

has reached the maximum of improvement, but should be taken much earlier at the time when the patient has developed enough motion and confidence to really go ahead and use the part. From this point, improvement is chiefly a matter of time with an occasional check-up and encouragement by the physician.

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these fractures, particularly those of the phalanges, lower end of the radius, shaft of the humerus and upper end of the humerus. This treatment must be preceded by proper reduction of the fracture, and combined with adequate protection. When properly employed, physical therapy will sometimes determine the difference between a good and a bad result. In seeking to bring about functional recovery after a fracture of the upper extremity, it is of the greatest importance to regard the limb as a whole and to avoid focusing the attention only upon the region immediately adjacent to the injury. Stiffness of the fingers and hand with loss of function may well follow an injury involving a region as remote as the shoulder, and stiffness in the region of the shoulder may be the consequence of an injury affecting the wrist. In the application of physical therapy it is therefore important to treat all the joints and muscles, and to restore all motions. It is also necessary to inspire the patient with the will to work. No amount of physical therapy will make up for the persistent avoidance of movement by the patient. In personally administering massage and mobilization in the early stage of treatment, the surgeon has an unequalled opportunity for impressing upon the patient the importance of movement in reëstablishing function and the necessity for active coöperation on his part. If the surgeon fully capitalizes this opportunity, a large part of the disabilities due to stiffness of the fingers and other joints will be avoided.

Fractures of the Hand.—Fractures of the region of the hand include injuries of the phalanges and metacarpals. These injuries, unfortunately, are commonly considered minor and are often treated by physicians of little experience, whereas actually they represent problems of the first magnitude and demand the highest skill in their solution. Frequently multiple and involving the bones of several fingers as well as of the hand, the results are often distressing and necessitate the later amputation of one or more digits in order to get rid of an impediment to the function of the remaining fingers. The common causes of failure, in so far as they may be ascribed to treatment, are incomplete reduction, too long fixation and lack of physiotherapeutic reëducation of the patient.

Phalangeal Fractures.—Phalangeal fractures if accompanied by bony deformity require immediate reduction and splinting. Alignment is usually best maintained with the joints fixed in flexion. This position overcomes deforming muscle pulls, and likewise favors the recovery of motion. Traction must frequently be applied either by means of adhesive plaster applied to the skin or by a needle or wire passed through a phalanx. Constant traction is usually secured in combination with some form of the banjo splint. Many of these fractures are compound with extensive injury of the tendons and soft tissues, and

inevitably result in joint stiffness due to adhesion of the tendons in spite of the best treatment.

The point of chief importance in the treatment of these injuries after securing reduction is to reduce fixation to the minimum. Union develops rapidly, and at the end of two weeks there is very little risk of displacement. Physical therapy may be started at the end of one to two weeks, depending upon the nature of the injury, the splints being removed temporarily for treatment. In fractures without deformity it may be employed from the beginning. All splints should be removed at the end of three weeks and active movement and light use permitted.

Physical therapy should consist of the warm whirlpool bath, followed by superficial massage and relaxed motion of all the digits. The uninjured fingers should receive treatment as well as the injured ones. Active motion with the injured phalanx supported manually should follow with movement through as great an arc as possible. The movements should be performed individually for each of the joints. The treatments should be repeated daily for the first week or two, and thereafter on alternate days. At the end of three to four weeks only active or assisted movements should be made, and thereafter chief reliance should be placed upon supervised active use. Contrast bathing of the hand at home is also useful. The patient should be given exercises of squeezing a rubber or woolen ball, and shifted gradually into playing scales on the piano, typing and other kindred activities. Physical therapy after five weeks is usually a waste of time.

Metacarpal Fractures.—Fractures involving the shafts of the metacarpal bones in contrast to those of the phalanges rarely give rise to functional impairment. They are usually accompanied by posterior angulation or bowing and by dropping of the knuckle. This deformity may usually be corrected by flexion of the metacarpophalangeal joints to relax the pull of the volar interossei muscles and by pressure from the palmar side against the head of the metacarpal. These indications are met by flexing the fingers over a molded splint or roller bandage and fixing them in this position. Fixation must usually be maintained for about three weeks. As a rule, there is little difficulty in the recovery of finger function, and formal physical therapy is rarely needed. Contrast bathing at home, active exercises and use are generally adequate.

Fractures of the heads of the metacarpals and multiple fractures of the phalanges and metacarpals are much more serious and frequently require constant traction for the correction of deformity, accomplished usually by some form of the banjo splint. This treatment is dangerous from the functional standpoint and may lead to stiffness, in comparison with which a little bony deformity may seem of slight importance. The stave fracture of the proximal end of the metacarpal of the thumb, usually designated as Bennett's fracture, is likewise of functional significance because it implicates the joint, and

may cause impairment of, or pain on, motion. These fractures require traction to accomplish reduction with the thumb in the position of wide abduction and partial apposition. Traction must usually be maintained for a period of about three weeks before sufficient union is obtained to prevent recurrence of the deformity.

Physical therapy is distinctly indicated in the cases of multiple fracture of the bones of the hand and likewise after fractures of the metacarpal heads and Bennett's fracture. The treatment should be started just as soon as traction is discontinued, usually at the end of two to three weeks. It should consist of the warm whirlpool bath, massage, passive, assisted and active movements of the interphalangeal and metacarpophalangeal joints. Intensive treatment should be given daily during the first week or two if there is much tendency to stiffness. Active exercises to be done at home, as well as under the supervision of the technician, and contrast baths should be prescribed at the end of four or five weeks. Thereafter the patient should be constantly urged to active use and exercise of the fingers and hand, and some form of suitable occupational therapy should be suggested, such as piano playing, typlog, knitting, sewing, cutting out paper patterns, etc., and these should be persisted with until the stiffness has entirely disappeared.

Fractures of the Carpal Bones.—The most common injuries of the carpal bones are fracture of the scaphoid and dislocation of the semilunar. These may occur separately or in combination. Instances of fracture of the other carpal bones are occasionally seen, but such lesions are rare and not typical. The principles of treatment necessary for a successful result after carpal fractures are, first, early diagnosis; secondly, immediate reduction of displacement when present; and thirdly, long-continued immobilization and protection of the fractured region. Physical therapy is usually contraindicated.

Fractures of the Scaphoid.—The common injury of the scaphoid bone is a transverse fracture through the "waist," usually not associated with much separation or displacement of the fragments except when accompanied by dislocation of the semilunar bone, in which case the distal fragment is displaced posteriorly along with the distal row of the carpus and comes to lie in a dorsal relation to the proximal fragment and the semilunar.

Fractures of the scaphoid bone constitute a class apart from other bony injuries because of their notorious tendency to nonunion. This is due to the fact that the blood supply to one of the fragments, usually the proximal, is shut off and that bony union can only be brought about by the ingrowth of capillaries from the viable fragment and creeping substitution of the dead bone by living bone. The closest approximation of the fractured surfaces and avoidance of all motion between the fragments are the necessary conditions for the

completion of this process. The anatomic studies of Berlin [22] showed that the fragments were brought into closest apposition when the wrist was placed in a position of 45 degrees dorsiflexion with radial deviation. Fixation of the wrist in this position should be secured by the application of plaster splints extending from below the elbow to the metacarpophalangeal joints and including the first phalanx of the thumb. A policy of complete immobilization of the wrist should be followed for a period of six weeks.

When fractures of the scaphoid are subjected to movement the result is almost invariably nonunion. For this reason physical therapy is completely contraindicated until after the splints have been removed. During the period of complete fixation of the wrist, the fingers may be used in so far as permitted by the splints, and many tasks of a light nature may be performed with benefit in respect to the maintenance of finger flexibility. Following the removal of the splints, it is advisable for the patient to wear a steel reënforced leather brace extending from the metacarpophalangeal joints to the middle of the forearm but leaving the fingers and thumb free. This may be removed daily for contrast bathing and active exercises of the wrist in flexion and extension and of pronation and supination of the forearm. Above all, active use of the hand for all tasks with the brace in place should be urged. This is the best form of physical therapy, and many patients have been able to resume their regular work, often of a heavy nature, without being handicapped by the brace. The brace can usually be discontinued at the end of three months, and at this time there is generally complete restoration of function.

Dislocation of the Semilunar Bone.—While it is our purpose to consider in this chapter fractures rather than dislocations, anterior luxation of the semilunar bone requires mention because of its frequent association with fracture of the scaphoid. The treatment of isolated dislocation of the semilunar bone is reduction by either the closed or open method as soon as possible after the diagnosis has been made. When the patient is seen early, that is, within three or four days of injury, reduction can usually be accomplished by the closed method. When seen later, reduction can usually only be brought about by open operation. When the patient is not seen until three or four weeks after the injury, it is usually advisable to excise rather than to replace the dislocated bone.

Following reduction by either the closed or open method, the wrist is splinted in a position of dorsiflexion for a period of about four weeks, but the fingers and thumb are left free. During this period active use of the fingers and thumb should be urged for all tasks, and if full coöperation is obtained, the patient will appear to be handicapped very little by the presence of the splints. Due attention should also be paid to the prevention of stiffness in the elbow and shoulder. Upon removal of the splints, function of the wrist is usually quickly

reëstablished by active use supplemented by contrast bathing and active exercises performed at home. As a rule, there is little need of formal physical therapy administered by a technician except in the case of long-standing dislocations when the displaced semilunar must be excised. In such cases there is apt to be considerable stiffness of the wrist and fingers associated with pain, and these conditions can be ameliorated by whirlpool baths, massage, and active and passive exercises, beginning as soon as the healing of the operative wound permits.

When dislocation of the semilunar is associated with fracture of the scaphoid, reduction should be brought about by the closed method, and the after-treatment differs in no way from that of isolated fracture of the scaphoid.

Fractures of the Lower End of the Radius.—Fractures of the lower end of the radius are, with the exception of fractures of the clavicle, the most frequently encountered of all bony injuries and constitute a large and important group of fractures. Included in the group are several different types of fracture which may be differentiated both on an anatomic and mechanistic basis, but it is not within the scope of this chapter to deal with each of these separately. By far the most common type of fracture is that produced by a fall on the outstretched hand with the wrist in the position of dorsiflexion, or by a blow on the palm as from backfiring while cranking a gasoline motor, the wrist being in the same position. This fracture mechanism was first described by Abraham Colles,[24] and is usually known by his name. Our discussion will be limited to a consideration of the physical treatment of Colles' fracture and also of the fractures of the lower radial epiphysis, likewise an important group.

Colles' Fracture.—By the term *Colles' fracture* we mean to designate fractures through the lower cancellous end of the radius produced with the wrist in hyperextension. The pathology of this fracture is well known and requires no special description here beyond calling attention to the fact that it may be transverse and not involve the articular surface, or comminuted with extensive involvement of the joint surface. Impaction, according to Darrach, is present in about one-third of the cases. Deformity may be absent but is generally present and often to an extreme degree. It consists of a posterior displacement of the distal fragment, which is at the same time tilted so that the articular surface faces backward and distally instead of forward and distally. The distal fragment is also rotated in the direction of supination on the long axis of the radius. The displacement of the distal fragment causes disruption of the inferior radio-ulnar articulation, with either the tearing of the triangular fibrocartilage or a fracture of the ulnar styloid to which it is attached. This frees the distal

fragment from the head of the ulna, and the latter is left projecting on the volar surface of the wrist.

The treatment of this fracture involves two problems, first, that of correction of the bony deformity, and second, that of obtaining functional restoration. The solution of these problems is by no means identical, and demands not one but two answers. It does not follow that because bony deformity is corrected functional recovery will be the natural sequence, nor, on the other hand, can it be predicted that a fracture with uncorrected bony deformity will not in the end provide a strong and useful wrist. Anatomic restoration is the proper foundation for functional recovery, but it is necessary to work for the latter, not to wait for it.

Correction of displacement is of fundamental importance in the treatment of these injuries and should be brought about by the closed manipulative method under local or general anesthesia as soon as possible after the injury. Impaction should be broken up, the distal fragment pushed forward into normal relation with the head of the ulna, and the backward tilting and rotation corrected. Reduction should be maintained by the application of retentive splints. These should extend from the metacarpophalangeal joints to the upper forearm, leaving the thumb and fingers free for all movements. In this connection it is important to realize that the level of the metacarpophalangeal joints is on a line about one inch proximal to the web of the fingers and corresponding to the distal transverse crease in the palm. If the splint projects beyond this point, flexion of the fingers will be hindered and functional recovery delayed. The test of complete freedom of finger movements is whether the tip of the thumb can be approximated to the tips of all the fingers. As a rule, the wrist must be fixed in moderate flexion with the forearm pronated. Our own preference for splinting is anterior and posterior plaster splints because of the ease of molding and adapting them to the parts, and their light weight and small bulk. A sling completes the dressing.

Physical therapy plays an important rôle in the treatment of Colles' fractures. Routine surgical care of the splints is not sufficient and will result in many stiff, disabled hands and delayed convalescence unless supplemented by treatment specifically directed to promoting recovery of function. My own practice is to begin light superficial massage and passive mobilization the day following the reduction. Prior to the reduction, when there has been considerable swelling, I have administered massage for about twenty minutes, often with noticeable improvement in the circulation. The day after the reduction the dorsal splint is removed, leaving the wrist resting on the anterior splint, which is supported on a cushion. Light, rhythmical stroking is administered over the entire back of the hand, wrist and forearm. The dorsal splint is then reapplied, and an assistant lifts the patient's wrist, holding it against the splint while the anterior splint is removed and the anterior surface of the wrist and forearm similarly treated. The

reëstablished by active use supplemented by contrast bathing and active exercises performed at home. As a rule, there is little need of formal physical therapy administered by a technician except in the case of long-standing dislocations when the displaced semilunar must be excised. In such cases there is apt to be considerable stiffness of the wrist and fingers associated with pain, and these conditions can be ameliorated by whirlpool baths, massage, and active and passive exercises, beginning as soon as the healing of the operative wound permits.

When dislocation of the semilunar is associated with fracture of the scaphoid, reduction should be brought about by the closed method, and the after-treatment differs in no way from that of isolated fracture of the scaphoid.

Fractures of the Lower End of the Radius.—Fractures of the lower end of the radius are, with the exception of fractures of the clavicle, the most frequently encountered of all bony injuries and constitute a large and important group of fractures. Included in the group are several different types of fracture which may be differentiated both on an anatomic and mechanistic basis, but it is not within the scope of this chapter to deal with each of these separately. By far the most common type of fracture is that produced by a fall on the outstretched hand with the wrist in the position of dorsiflexion, or by a blow on the palm as from backfiring while cranking a gasoline motor, the wrist being in the same position. This fracture mechanism was first described by Abraham Colles,[28] and is usually known by his name. Our discussion will be limited to a consideration of the physical treatment of Colles' fracture and also of the fractures of the lower radial epiphysis, likewise an important group.

Colles' Fracture.—By the term *Colles' fracture* we mean to designate fractures through the lower cancellous end of the radius produced with the wrist in hyperextension. The pathology of this fracture is well known and requires no special description here beyond calling attention to the fact that it may be transverse and not involve the articular surface, or comminuted with extensive involvement of the joint surface. Impaction, according to Darrach, is present in about one-third of the cases. Deformity may be absent but is generally present and often to an extreme degree. It consists of a posterior displacement of the distal fragment, which is at the same time tilted so that the articular surface faces backward and distally instead of forward and distally. The distal fragment is also rotated in the direction of supination on the long axis of the radius. The displacement of the distal fragment causes disruption of the inferior radio-ulnar articulation, with either the tearing of the triangular fibrocartilage or a fracture of the ulnar styloid to which it is attached. This frees the distal

fracture of the lower end of the radius in children, usually between the ages of seven and twelve years. Such fractures require careful reduction and retentive splinting for a period of about four weeks. The same methods are employed as in the treatment of Colles' fracture, although greater difficulty may be encountered in retaining reduction than in the latter. There is less need for physical therapy in the treatment of the epiphysial fractures than in Colles' fracture on account of the youth of the patients which is favorable to the rapid recovery of function. The physician may begin the administration of massage and relaxed movement at the end of two weeks, and this should be continued on alternate days until the splints are removed. Active use of the splinted hand, the fingers having been left free, should be encouraged from the end of the first week. As soon as the splints have been removed, contrast baths should be given at home together with regular exercise treatment until recovery is complete. Usually there is no necessity for formal baking and massage treatments.

Fractures of the Bones of the Forearm.—Fracture of Either the Radius or Ulna Alone.—Fractures involving the shaft of one of the bones of the forearm, the other remaining intact, are, on the whole, fairly simple problems. The degree of displacement is rarely severe due to the fact that the unfractured second bone serves as a splint and exerts a limiting action. The bony deformity can generally be corrected by closed methods, although occasionally open reduction may be required. Fixation is usually obtained by the application of retentive splints extending from the metacarpophalangeal joints nearly to the axilla with the elbow flexed either at a right angle or in complete extension and the forearm in varying positions of pronation or supination, depending upon the type of fracture.

Physical therapy may usually be employed from about the fourteenth day after injury. Earlier treatment is likely to be dangerous. Active exercise and use of the digits should, however, be insisted upon from the beginning. At the end of two weeks, superficial massage may be employed, the arm being supported on one splint while the other is removed. Depending upon the location and mobility of the fracture, relaxed motion may be performed at either the wrist or elbow, choosing the articulation farthest removed from the seat of injury. At the end of three to four weeks, depending upon the progress of callus formation, the arm may be carefully lifted from the splints, supported by cushions and more general treatment administered in the form of superficial massage with relaxed motion of the fingers, wrist and elbow. Generally the last movements to be performed are those of pronation and supination, as these are attended by the greatest danger of displacement. The physician should be guided as to these by the appearance of callus formation by roentgen rays, and he should wait until there is clear evidence of new bone formation. The duration of splinting is variable in fractures of one of the bones of the forearm; in

fingers are massaged individually and then mobilized passively and actively with assistance. The splints are then reapplied and bandaged in place. The elbow is next flexed and extended, and the shoulder abducted and rotated. The patient is instructed to exercise the fingers, the elbow and shoulder regularly every day. The treatment is repeated the following day, and thereafter on alternate days. At the end of four days the patient is instructed to lift the splinted wrist out of the sling whenever sitting and to begin to use the fingers for light tasks such as holding a newspaper, turning the pages of a book, and in connection with the toilet, dressing, undressing, etc.

At the end of one week the wrist is lifted out of the splints during the treatment and supported on a cushion. Following the massage of the dorsal surface, the region of the fracture is supported by one of the physician's hands while, with the other, gentle, relaxed motions are made of extension and flexion of the wrist, and of pronation and supination of the forearm. While the wrist is supported in extension the patient is requested to extend repeatedly the fingers and to clinch them in a fist. Attention is also given to the elbow and shoulder. At this time, also, the patient is instructed to discontinue the use of the sling, elevating the hand only when the fingers become swollen as a result of the dependent position. Active use of the hand is increased to include assistance in eating, dressing, shaving or caring for the hair.

At the end of two weeks the use of heat, either by an electric baker or from a whirlpool bath, is begun as a preliminary to massage and mobilization. The extent of the movement is increased, and active and assisted movements occupy a larger part of the treatment, but the region of the fracture is still supported manually. At this time the anterior splint is discontinued and the wrist and forearm are bandaged into the dorsal splint only. This permits a greater range of active use of the fingers. All splints are discontinued at the end of three weeks except in the severely comminuted fractures, which usually require protection until the end of four weeks. Temporarily after the removal of the splints the patient's comfort is promoted by the use of a bandage about the wrist or by a leather wrist strap. From this time on the patient employs contrast bathing at home, performs active exercise and is encouraged to use the hand actively for all tasks except lifting or pushing. He is required to report twice a week during two additional weeks for supervised treatment by the technician.

Functional recovery is usually complete by the end of six weeks, and a surprising variety of active use of the hand is usually possible for some time earlier.

Fractures without displacement require splinting for two weeks only, and the whole plan of treatment in respect to movement and use may be speeded up correspondingly.

Epiphysial Fractures of the Lower End of the Radius.—Separation of the lower radial epiphysis occurs as a variation of

treatment lies in a correct appraisal of the pathologic changes and the amount of bony deformity, and whether or not the displacement is of a type to cause interference of movement. If it is, then the only remedy is operation with the removal of the loose fragment if the remainder of the head is still capable of function, or with complete excision of the head if there has been extensive comminution of the head or a displaced fracture through the neck of the radius. In the case of the rare epiphysial fractures of the upper end of the radius, occasionally encountered in children, open reduction may be performed instead of excision.

When fractures of the head or neck of the radius are treated, either by removal of the loose fragment or by excision of the head, no splinting is required beyond soft dressings, bandage and sling. The problem of securing union of the fracture has been eliminated by the removal of the fragments, and the reparative process is limited to the healing of the raw bony surface and damaged soft parts. Passive and assisted movements of limited extent may usually be begun at the end of three to four days, and the patient may be encouraged to perform active pronation and supination as soon as he has recovered from the acute effects of the operation. As soon as wound healing has been obtained, usually at the end of one week, the active efforts of the patients may be aided by electric baking, superficial massage and effleurage, and by relaxed and assisted movements of the elbow. Usually the arm may be removed from the sling for the performance of light tasks at the end of three weeks, and at the end of four weeks this support is removed and active use encouraged. Physical therapy should usually be continued until the end of eight weeks, with radiant heat, effleurage, active exercises and forced assisted movements.

Fractures of the head and neck of the radius with little or no displacement usually require splinting with the elbow in the position of acute or right-angle flexion for a period of about three weeks. Superficial massage and relaxed motion of the elbow in flexion and extension may be administered, however, from the beginning, the splint being removed for the treatment. As a rule, the rotary movements of the forearm, which are the most painful and likewise the most dangerous in respect to causing displacement, should not be started until the end of one to two weeks, the indication here being the disappearance of pain on motion. At the end of two to three weeks, more intensive treatments can generally be given, consisting of radiant heat, effleurage, assisted and active movements. Fairly complete recovery after such injuries ought to be obtained in from six to eight weeks, although there may be an obstinate limitation of complete extension of the elbow persisting for several months before it finally disappears.

Special warning ought to be given in connection with fractures of the head and neck of the radius of the danger of the development of an ossifying hematoma or myositis ossificans. Many of these fractures are complicating injuries of posterior dislocations of the elbow

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Fractures of Both Bones of the Forearm.—Fractures of both bones of the forearm are among the most difficult of all fractures to treat. They are frequently ottended by severe displacement, reduction is difficult and often necessitates resort to the opeo method, and, in addition, union is frequently delayed. Under these circumstances physical treatment is dangerous and the only safe rule is to postpone it until consolidation is well odvanced. During the interval, efforts should be concentrated upon obtaining mobilization of the fingers and thumb with the splints in place. This task is often difficult eoough, but at the same time of extreme importance, as the muscles arise in or span the region of the fracture and have often suffered considerable damage. Unless motion is started early and cootinued, there is likely to be resulting stiffness which may imperil the functional result. The splints should be trimmed well back into the palm in order to allow unhampered motion of the digits. In additioo, exercises of the shoulder that put it through its full range of motioo should be performed regularly.

The time required for union of fractures of both bones of the forearm may vary from six to ten weeks or even looger. It is generally advisable to follow a policy of complete fixation of the fracture until this result is obtained. Relaxed movements of the wrist and elbow, preceded by gentle stroking massage, may usually be started one to two weeks before the removal of the splints. The movements of pronation and supination are the most difficult to recover, and, indeed, are often permanently restricted in greater or lesser degree, depending upon whether or not the reduction has been complete, the amount of callus formation, and the extent of soft part injury and scar development in the interosseous space. The amount of assistance that may be given in recovering these motions depends upon the surgeoo's appraisal of the causes of limitation and how completely these may be overcome by gradual stretching. After removal of the splints, baking, effleurage and assisted movements may be given, and active use prescribed. As a rule, after two to four weeks of treatment, reliance should be placed upon active exercise, and the other forms of physical therapy stopped.

Fractures of the Elbow.—Fractures of the Head and Neck of the Radius.—Fractures of the head and neck of the radius carry the menace of restriction of the rotary motions of the forearm and limitation of flexion and extension of the elbow, and demand special attention in order to preserve complete function. The crux of the

treatment lies in a correct appraisal of the pathologic changes and the amount of bony deformity, and whether or not the displacement is of a type to cause interference of movement. If it is, then the only remedy is operation with the removal of the loose fragment if the remainder of the head is still capable of function, or with complete excision of the head if there has been extensive commioution of the head or a displaced fracture through the neck of the radius. In the case of the rare epiphysial fractures of the upper end of the radius, occasionally encountered in children, open reductioo may be performed instead of excision.

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operation was unnecessary. His results were confirmed by Pirie Watson,[14] who published the records and roentgenograms of two patients whom he had treated by Lucas-Championnière's methods. In both cases there was well-marked separation of the fragments in the beginning, but bony union was obtained, although with some deformity. Recovery was stated to have been complete in from four to six weeks. The elbows were enveloped in cotton-wool dressings and supported in slings at a right angle; massage and mobilization were started immediately. Both Lucas-Championnière and Watson laid great stress upon the necessity of pressing the proximal fragment against the distal with the fingers during motions of extension; otherwise the proximal fragment was likely to become adherent to the underlying tissues and thus interfere with function of the triceps.

Fractures of the olecranon process without displacement may be treated in a sling with only bandage support, or at the most in extension with a straight splint for one week followed by a sling. Massage and mobilization should be started immediately, the motion being of the relaxed type for the first two weeks, followed by assisted and active movements. Use may be permitted at the end of four weeks.

Fractures of the Lower End of the Humerus.—Fractures of the lower end of the humerus include a variety of injuries, and it is necessary to consider these separately as the problems are different.

Supracondylar or Diacondylar Fractures.—The majority of these fractures are encountered in children. The injury is generally diacondylar, that is, transverse at the level of the condyles rather than supracondylar or above the condyles. The fracture line slopes obliquely downward from behind forward, and except in the rare injuries of the flexion type the distal fragment is displaced posteriorly. When satisfactory reduction is obtained and even sometimes when it is not, the end-results are almost always excellent with complete recovery of motion. The carrying angle may be somewhat altered, but this is of functional significance only when it is decreased, not when it is increased. The recovery of complete extension of the elbow is often slow, but with time it almost always becomes complete or at the most lacks only a few degrees of normal.

Reduction should be accomplished as early as possible after injury by the closed method with the aid of anesthesia. Reduction is maintained by fixing the elbow in the position of acute flexion, either by bandage or by a posterior plaster splint. Care is necessary in watching the circulation, both during the reduction and afterward, as this injury is the most common cause of the dreaded Volkmann's ischemic contracture. Whenever there is an absent radial pulse, or when the pulse disappears during the reduction, or when there is marked swelling, correction of the bony deformity should be postponed and measures taken to improve the circulation. When the hand is cold and white, and motion of the fingers cannot be obtained, and the pulse is absent, an

with accompanying rupture of the capsular ligaments and hematoma formation. The fracture of the upper end of the radius adds to the hemorrhage and releases bone-forming elements in the traumatized tissues, which offer ideal conditions for widespread ossification. The additional trauma of operation may further stimulate this process. Certain it is that extensive calcification in the anterior capsule is seen not infrequently in these fractures, particularly those that have been subjected to operation, and it may cause interference with function and sometimes complete ankylosis. The characteristic symptoms are diminution of motion just at the time when an increase should be expected, pain on use, and evidence of muscle spasm. The diagnosis is confirmed by roentgen-ray examination, which shows cloudiness or beginning ossification in the soft parts anterior to the elbow. When the development of this condition is suspected or found, the elbow should be immediately immobilized with cessation of all physical therapy and of activity of any kind that may represent a source of irritation. Only when the process of ossification has reached an end-point can anything be done to overcome the condition. Then baking, massage, and active exercises may be started and active use resumed. After an interval of one year, if considerable limitation of motion persists, the area of calcification can be excised with good chance of cure.

FRACTURES OF THE OLECRANON PROCESS.—The treatment of fractures of the olecranon process depends upon whether or not there has been separation of the fragments. In fractures with displacement the situation is analogous to that in fracture of the patella, and we believe that the best results are obtained by operative replacement of the fragments and suture. The purpose of the operation should be to fix the fragments so securely that movement may be permitted immediately without the necessity of external fixation. The suture material must therefore be strong enough to withstand considerable strain, and we favor the use of either fascia lata or wire. When the fragments are drilled and snugly approximated with these materials, then the elbow may be flexed and extended without danger, and no postoperative fixation is required beyond that provided by a large, soft dressing and sling. Active and passive mobilization may be started as soon as the acute operative reaction has subsided. Massage may be administered as soon as the wound has healed and, after two weeks, may be followed by assisted movements and active exercises in flexion and extension of the elbow. Active use may be permitted at the end of four weeks, and complete functional recovery is usually obtained in from eight to twelve weeks.

It is only fair to add that Lucas-Championnière,[37] who to his last days was an ardent advocate of the operative repair of fractures of the patella and who earlier advised operation also for fractures of the olecranon, came later to feel that the results obtained by his method of massage and mobilization in the latter injuries were so good that

joint capsule, representing the spreading of ossification from small fragments evulsed with the capsular ligaments. Occasionally these calcified bodies must be removed, but this should only be done after thorough efforts have been made to restore function and it has been established that they are responsible for the persistent disability.

Uncomplicated fracture of an epicondyle is usually a simple injury best treated by a sling and bandage. Massage and relaxed motion may be started immediately in adult patients but is scarcely needed in children. Active motion may be permitted at the end of one week and the sling may be discontinued at the end of two or three weeks. The fragment frequently fails to unite by osseous union, but this rarely gives rise to any symptoms.

Condylar and Intercondylar Fractures.—Fractures involving a single condyle, either the medial or lateral, or of both the condyles in the form of the intercondylar T type are difficult injuries to treat, and rarely recover without some degree of functional impairment. Accurate reduction should be sought by all possible means, but the problem is individual in each case, and no general rule can be laid down. Even the experienced surgeon must often proceed by the method of trial and error. The displacement may be insignificant, in which case no reduction may be required, but this is rare. In others, it may be possible to secure satisfactory reduction by the manipulative method followed by fixation of the elbow in whatever position of flexion or extension seems best to retain the correction. In other cases, continuous traction may be indicated by means of adhesive to the skin of the forearm or Kirschner's wire through the olecranon process, or it may be advisable to perform an open reduction. In some of the more difficult cases all of these methods may be tried in rotation, and the result may still remain unsatisfactory. While reduction is important, prolonged fixation of these fractures is unwise and will result in stiffness of the elbow regardless of the perfection of the reduction. Some compromise has to be reached, and this generally resolves itself into a choice between two plans of treatment; first: to secure reduction by manipulation or traction, and to begin mobilization at the end of two to three weeks, which is too early to render exercise treatment entirely safe; or, second, to obtain reduction by operative means with internal fixation of the fragments by one or another method, but secure enough to allow of doing away with external splinting and of beginning mobilization of the elbow as soon as the acute operative reaction has subsided. The latter course has much to commend it, but it often proves impossible to reduce the fragments perfectly, and the additional trauma of the operation may occasion secondary fibrous tissue formation sufficient to impede complete recovery.

In case of extensively comminuted fractures or in elderly individuals with injuries of a more simple type, it may well be the best policy not to aim for reduction which would be imperfect at best, but instead to try to develop function by employing massage and mobilization from

incision should be immediately made at the front of the elbow to expose and release the vessels and to evacuate the hematoma and relieve the tension.

In the uncomplicated fractures the dressing should be taken down at the end of 48 hours and the elbow inspected. In the absence of blebs, light stroking massage may be administered over the lateral, medial and posterior surfaces, and the elbow may be passively extended and flexed through a range of 10 to 20 degrees; the dressings are then reapplied. This treatment should be repeated on alternate days over a period of about three weeks, gradually gaining in extension until the right-angle position is attained. At this time the splint or other dressings may usually be removed and a neck sling substituted, which is gradually lowered to the right angle. At the end of four weeks the mother may begin to remove the arm from the sling twice a day and assist the child in performing active exercises. At the end of four to five weeks all support may be discontinued and active use encouraged.

The difficulty in the use of physical therapy in this fracture is the age of the patient and the child's timidity and fear of pain. The confidence of the child can be obtained only by being careful not to cause pain at any time, by being patient and by not hurrying. If "scenes" result in spite of every effort, it is better to give up all efforts at physical therapy. Also because of the fact that most of the patients are children, there is always the danger of a fall during play and of secondary injury, and this makes it necessary to protect the fracture for a longer period than would otherwise be necessary.

Lindsay [24] has reported successful results from the early use of massage and relaxed motion in fractures of the elbow, employing a more radical technic than we have followed. I have had the pleasure of seeing some of Lindsay's cases, and the results appeared to correspond in every way to what he had claimed. I feel, however, that it is a very specialized technic and hardly safe in ordinary hands. In general, children recover so rapidly and completely after supracondylar fractures that it is unnecessary to take any risks with them.

Fractures of the Epicondyles.—Fracture of the medial epicondyle, either in the form of a simple fracture or of an epiphysial separation, is a common injury, while fracture of the lateral epicondyle is rare. It is a frequent complication of dislocation of the elbow but gives rise to no difficulty unless it becomes caught in the intra-articular space during the reduction, in which case, because it carries the ulnar nerve with it, there is likely to be injury of the nerve with the characteristic paralysis. An immediate roentgen-ray examination should be made following the reduction, to guard against this complication, and when the fragment is shown to be lying in the cavity of the joint, its removal by operation is indicated together with transposition of the nerve to the front of the elbow. Another complication of fracture with dislocation is the development of calcified bodies in the medial portion of the

advantage in attempting manipulative reduction with the aid of an anesthetic in the hope of being able to enmesh or to interlock the fragments. When successful, the after-treatment is simplified; when unsuccessful, nothing has been lost. When the fracture is either of the oblique or comminuted type, manipulative reduction is foredoomed to failure and ought not to be attempted. In these cases light superficial massage should be administered to relax the muscles, and then without any anesthesia the angular deformity should be gently corrected, and the coaptation splints and the dressings applied. As a rule, no great difficulty is experienced in controlling the alignment in this manner, and as the spasm of the muscles is overcome by daily massage treatments, the reduction becomes more and more perfect, the weight of the unsupported elbow providing a certain traction force. If any difficulty is experienced in obtaining reduction, particularly in the oblique or transverse fractures, it is usually because tissue has been interposed between the fragments, and this is an indication for operative reduction, usually with internal fixation of the fragments by one or another method. Following operation, rigid splinting should be employed for the first two weeks, but after this, massage and mobilization may be begun.

When possible, treatments should be given daily during the first two weeks, and thereafter on alternate days. They are best given with the patient seated, the back supported and the forearm resting on a cushion laid across the patient's knees. Massage of the superficial type should extend from the wrist to the shoulder, and, after relaxation is obtained, gentle passive movements of the elbow and shoulder should be performed, also not neglecting the fingers and wrist. The motions of the shoulder should be made with the elbow and forearm supported by the physician's hands and carefully and in a limited way in order not to cause movement of the fragments. The last movements to be started are those of rotation of the shoulder, and these should generally be postponed until the end of ten days. All of the early treatment demands the greatest skill and judgment, and ought not to be administered by any one but the physician in charge. Healing progresses rapidly, and the changes can be followed from day to day, both in the appearance of the arm, the firming of the fragments, the development of callus and the increase of the range of joint movement. At the end of two weeks the fragments are glued together, and the circular body bandage can be discontinued. Callus formation is usually well vanced by the end of four weeks and demonstrable by roentgen ra Clinically, sound union is present at the end of five to six weeks, an at this time the matter of administering further treatment may be delegated to a technician. It should include radiant heat, superficial massage and effleurage, and active and assisted exercises for all the joints of the upper extremity. Occasionally the development of bony union may require a little longer time than the period stated, but this is rare, and the gratifying thing about this method of treatment is the

the beginning. When this plan is adopted the arm should be suspended from an overhead frame with the patient recumbent, by means of adhesive traction to the forearm, and with the elbow in right-angle flexion for the first week or two. This method relieves pain, helps to overcome swelling, and permits a certain amount of active flexion and extension of the elbow. Massage and passive mobilization should be administered daily, the traction being released temporarily for this purpose. At the end of two weeks the traction is discontinued, a bandage applied to the elbow, and the patient allowed to be up with the arm in a sling. Treatments should be given on alternate days with massage, passive, active and assisted movements. Passive and active exercises should be performed daily by the patient with the assistance of the uninjured hand. Active use for light tasks should be permitted at the end of four weeks, the sling may be discarded at the end of six weeks and full activity encouraged. I have seen some remarkable results achieved by this method in what were regarded as almost hopeless fractures. It seems as if some credence must be given to the theory that early mobilization clears obstructing fragments from the path of the olecranon and coronoid processes, and permits obtaining a range of function that would not be possible otherwise.

Fractures of the Shaft of the Humerus.—Fractures of the shaft of the humerus lend themselves remarkably well to treatment by the method of early massage and mobilization. For a time after the Great War it was considered necessary to employ traction to secure reduction of these fractures, and it was only in the course of time that it became evident that even a slight amount of continuous traction might lead to distraction of the fragments, and that this was a frequent forerunner of delayed union or nonunion. The alternative method of reducing the fracture by manipulation and retaining correction by the application of a plaster spica jacket is cumbersome and uncomfortable for the patient and all too often uncertain, in that reduction is frequently lost during the process of applying the plaster. The old-fashioned but time-honored method of splinting consisting of long coaptation splints, preferably of molded plaster of paris, extending from elbow to shoulder with a bandage to the forearm to control swelling and a narrow cravat sling to support the wrist, supplemented during the first week or two by a circular body bandage holding the arm to the chest, seems to me equally effective in maintaining alignment and has the additional great advantage of being easily removable and thus facilitating treatment by massage and mobilization. For it seems clear to me from actual experience that Lucas-Championnière's methods when properly applied are capable of overcoming muscle spasm and thus improving the alignment of fractures of the shaft of the humerus, and of likewise improving the circulation of the arm so that union is hastened and earlier functional recovery obtained.

When the fracture is of the transverse type, there may be some

advantage in attempting manipulative reduction with the aid of an anesthetic in the hope of being able to enmesh or to interlock the fragments. When successful, the after-treatment is simplified; when unsuccessful, nothing has been lost. When the fracture is either of the oblique or comminuted type, manipulative reduction is foredoomed to failure and ought not to be attempted. In these cases light superficial massage should be administered to relax the muscles, and then without any anesthesia the angular deformity should be gently corrected, and the coaptation splints and the dressings applied. As a rule, no great difficulty is experienced in controlling the alignment in this manner, and as the spasm of the muscles is overcome by daily massage treatments, the reduction becomes more and more perfect, the weight of the unsupported elbow providing a certain traction force. If any difficulty is experienced in obtaining reduction, particularly in the oblique or transverse fractures, it is usually because tissue has been interposed between the fragments, and this is an indication for operative reduction, usually with internal fixation of the fragments by one or another method. Following operation, rigid splinting should be employed for the first two weeks, but after this, massage and mobilization may be begun.

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rapidity of healing in contrast to the slow healing with other methods. The surgeon should be on the alert, however, to detect any evidence of tissue interposition between the fragments and to subject patients with this complication to operative reduction during the first 14 to 20 days.

Radial nerve injury, which is a relatively common complication of fracture of the shaft of the humerus, necessitates no particular change in the program of treatment. It is important to differentiate between a primary nerve injury, which is usually due to contusion or stretching of the nerve and therefore recovers promptly, and a secondary lesion, which is apt to be due to the nerve being caught between the fragments or to constriction by callus and hence requires surgical exploration. In all cases of radial nerve injury, stretching of the paralyzed extensor muscles should be prevented by supporting the fingers and wrist in the position of hyperextension on a long cock-up splint. This should be removed during the treatments for mobilization of the various joints.

Fractures of the Upper End of the Humerus.—Fractures of the upper end of the humerus include a variety of bony injuries such as fracture of the anatomic neck, fracture of the surgical neck, separation of the upper humeral epiphysis, and fractures of the greater and lesser tuberosities. In addition, any of these injuries may be complicated by dislocation of the shoulder. A classification based upon anatomic situation is confusing, however, and of little practical value, as the majority of the fractures are extensively comminuted and involve more than one region. Fractures of the anatomic and surgical necks and of the greater tuberosity are frequently present in combination in the same individual. From the practical standpoint it is more helpful to classify these injuries on the basis of the presence or absence of bony deformity, as this has a direct bearing on the treatment. Also there seems to be some degree of relationship between the amount of deformity and the type of fracture, displacement of the grosser sort being generally associated with the transverse fractures of the surgical neck, while slight or no displacement is more characteristic of the extensively comminuted fractures. The fracture-dislocations must also be considered in a separate group.

Fractures Associated with Little or No Displacement.—The large majority of the fractures with little or no displacement are made up of the comminuted fractures so commonly encountered in elderly individuals and especially women. This type of injury far outnumbers any other injury of the upper end of the humerus, and this together with its unfavorable age incidence accounts for its importance. The amount of comminution varies, but there is generally a giving way of a considerable part of the cancellous structure with involvement of both the surgical and anatomic necks and fracture of the greater tuberosity as well. Disalignment is variable, and generally slight or

absent, but there are exceptions in which the shaft is displaced medially or laterally with overriding.

The treatment of these fractures has undergone an evolution since the Great War. At first, with the lessons of the conflict in mind, it was considered necessary to splint the shoulder in a position of abduction, and this was accomplished either by the use of a Thomas splint or a so-called "airplane" splint. Continuous traction was usually employed in conjunction with the splint, and this was obtained by the application of adhesive plaster to the skin.

These methods either confined the patient to bed or necessitated the use of an encumbering appliance for several weeks, and often resulted in obstinate stiffness of the shoulder as a result of the long fixation. After trial of this method for several years, it began to be realized that the results were no better, if as good as those obtained formerly by other methods, and that it was unnecessary to subject the patient to this ordeal. For the last five years we have discarded these methods and adopted instead the plan of treatment by early massage and mobilization. The arm is fixed to the chest by a sling and circular bandage, and no other apparatus is used. Hospitalization of the patient is advisable for a period of at least two weeks. Roberts [29] studied the results, and these showed that complete recovery of function was obtained in almost all cases and in a much shorter time than when the shoulder had been fixed in abduction. In addition, this method of treatment has proved far more comfortable than the old and has avoided the necessity of recumbent treatment in the dorsal decubitus, which is often unsafe in these elderly patients because of the danger of hypostatic congestion of the lungs.

Massage of the light stroking type is administered when the patient is first seen. The treatment is given with both the patient and the physician seated, the patient's forearm and elbow being supported on a pillow placed across his knee. The entire shoulder and upper arm are treated. When relaxation is obtained, gentle passive motions of the shoulder are made in abduction and adduction, flexion (forward elevation) and extension. No rotary motions of the shoulder are attempted until the fragments have become glued together, usually at the end of two weeks. The treatments are best given every day for the first two weeks. At the end of one week a considerable range of motion is possible without pain, and pendulum movements of the shoulder may be started. These are performed with the patient standing and bending forward at the hips, the arm hanging free from the shoulder like a pendulum. In this posture the shoulder may be quite easily made to assume a position of 70 degrees forward elevation, whereas in any other posture it would be impossible to elevate the shoulder to this degree without pain. Gravity, acting in the long axis of the arm, exerts a traction effect upon the region of the fracture and thus protects it. Active swinging movements of both shoulders are now made by the patient in the anteroposterior plane (flexion and extension), then in

the lateral plane (abduction and adduction), and finally in a circular plane (circumduction). These exercises are repeated twice a day by the patient, and the number and extent of the movements are gradually increased. Massage and passive movements are continued daily or on alternate days.

At the end of two weeks the circular bandage holding the arm to the chest may be discontinued and the arm supported only by a sling. The patient is encouraged to use the hand for such light tasks as are possible with the arm at the side. The treatments by massage and passive motion may be decreased to three times a week, but the pendulum exercises performed by the patient are continued twice daily. Passive movements of the shoulder in rotation may also be started. At the end of three weeks the sensitiveness has generally disappeared and only the stiffness remains. The fragments are firmly cemented by soft callus. Radiant heat treatment of the shoulder may now be given preliminary to the massage and passive mobilization, and also free movements of the shoulder in abduction and adduction with the patient recumbent may be added.

At the end of four weeks a greater range of active use is possible, and the arm may be left out of the sling part time. Anything that may be done without pain is permissible. At this time the recumbent exercises of the shoulder are increased by the addition of forward elevation, and of rotation with the shoulder abducted. At the end of five weeks, active voluntary exercises with the patient standing erect may be begun. Weakness of the deltoid, infraspinatus and supraspinatus muscles, and stiffness in abduction and rotation persist for some time, and these movements may be aided by wall-climbing with the fingers and by a certain amount of assistance from the technician. Care is always employed to avoid pain. At the end of six to eight weeks from the time of injury, progress may be aided by the use of simple types of apparatus. A stick or wand four feet in length may be used; the patient grasps the ends in his hands, with his arms by his side, and then swings the arms back and forth in the lateral plane, the normal arm being used to push the injured shoulder into abduction. The patient next swings the arms forward and backward in the anteroposterior plane, elevating the shoulder, lifting the wand over the top of the head and dropping it down behind the neck, thus assisting in external rotation as well as in flexion and extension. The patient then passes the wand behind his waist, grasps its ends and moves it from side to side in the lateral plane, thus performing movements of abduction and adduction with the shoulders inwardly rotated.

From the end of the sixth week, active use should be encouraged in every way, especially for aid in personal care and dressing. Brushing the hair, shaving and performing other acts in connection with the toilet are important because they are frequently repeated and require dexterity. Swimming and practicing strokes in golf or tennis are to be encouraged for the younger patients; dusting, sweeping, and driv-

ing an automobile for the older ones. These help to recover the last few degrees of motion, but the normal uses of the arm with the shoulder abducted or elevated are extremely few; hence, emphasis must be continually laid upon the necessity of keeping up active exercises until complete functional recovery is obtained. Normal use of the shoulder is generally obtained in from eight to twelve weeks.

Fractures Accompanied by Displacement.—Many of the fractures of the upper end of the humerus are accompanied by gross displacement of the fragments. These are usually the transverse fractures of the surgical neck or fractures involving the epiphysial line. The head or proximal fragment is generally rotated into the position of abduction, while the distal or shaft fragment is separated from the head and displaced sometimes laterally, but usually medially into the axilla with gross overriding. The brachial nerves or vessels may be injured. Some of the comminuted fractures are likewise accompanied by displacement, but unless the shaft is actually separated from the head, we believe that better results will be obtained from treatment by massage and mobilization as outlined above without any attempt at reduction rather than by treating them with the aim of correcting all deformity.

Reduction of the deformity should be attempted as soon as possible after injury by closed methods, and when seen early, satisfactory replacement can usually be obtained. We believe from our own experience that reduction is rarely accomplished by continuous traction after the manipulative method has failed, and that in that case it is preferable to proceed forthwith to open operative reduction.

Reduction is usually best maintained by constant traction with the shoulder abducted. Adhesive strips are fixed to the upper arm, a Thomas splint is applied and the strips connected to a traction weight of five to eight pounds. The splint should be suspended from an overhead frame, to facilitate change of position in bed by the patient. Whenever possible the elbow should be fixed in right-angle flexion, as function is recovered much more quickly than when it has been fixed in extension. An alternative method of splinting is that described by Blake consisting of traction and suspension, with the shoulder abducted to the desired degree. Fixation by one or the other types of apparatus must usually be continued for a period of about three weeks, at the end of which time the arm can be brought down to the side without danger of recurrent displacement. When for any reason the patient must be made ambulatory at an earlier period, it is necessary to apply an airplane splint to maintain abduction.

Since many of the displaced fractures occur in patients of youthful or early adult age, there is less danger of stiffness as a result of immobilization of the shoulder than in the elderly patients with the comminuted fractures, and a good anatomic result should be sought as the best foundation for good function. As long as the shoulder and arm are fixed by apparatus, physical therapy cannot be employed. The

traction and suspension method of treatment allows a certain amount of shoulder and elbow motion, however, which to a considerable degree offsets this loss. When the apparatus is removed the patient is permitted to be up, carrying the arm in a sling, and at this time massage and mobilization treatments may be started. The general program corresponds to that described previously for fractures without displacement, except for the difference that it is started two to three weeks later, and the progression depends upon the rapidity of the functional response instead of the speed of callus formation.

Fracture-Dislocations.—The occurrence of dislocation of the shoulder in combination with fracture of the upper end of the humerus adds a serious complication to the latter injury and unfavorably modifies its prognosis. Fracture-dislocations in which the fracture involves the greater tuberosity are much more favorable than those in which the fracture involves the surgical neck, however, and it is important for purposes of treatment to differentiate between them.

Dislocations with Fracture of the Greater Tuberosity.—Fracture of the greater tuberosity is a frequent accompaniment of dislocation of the shoulder, the bony prominence being retained in position by its muscular attachments and left behind as the head displaces from the glenoid. This injury should be treated by immediate closed reduction, and replacement can usually be accomplished by either Kocher's or the traction method. Reduction of the dislocation also brings about reposition of the fracture with such secure apposition of the fragments that after immobilization for the period of one week the danger of redisplacement may be disregarded and the shoulder treated by massage and mobilization. Fixation is secured by sling and circular bandage with the arm by the side. The program of physical treatment corresponds in all respects to that outlined for fractures of the upper end of the humerus without displacement. With coöperation on the part of the patient, complete recovery of function can usually be expected in from eight to twelve weeks.

Dislocations with Fracture of the Neck of the Humerus.—Fracture dislocations of the shoulder in which the surgical or anatomic neck of the humerus is fractured represent a much more difficult problem. Reduction of the dislocation should be attempted by the traction method, aided by pressure on the head by the operator's fist in the axilla. Complete replacement is obtained in a certain number of cases, but more often the shaft separates from the head and is replaced in the glenoid cavity leaving the head behind. When this occurs operative reduction is indicated, but this raises the question of whether the head, which has been cut off from all blood supply, should be preserved and replaced in the glenoid, or should be removed. Either policy is likely to prove unsatisfactory as far as functional recovery is concerned, and considerable restriction of motion in abduction and rotation is to be expected. On the basis of our own experience, we are

inclined to favor replacement of the head whenever possible as the better policy.

Irrespective of whether the head is replaced or removed, the after-treatment necessitates fixation of the shoulder in a position of abduction for a considerable period, and this is usually accomplished by Blake's method of traction and suspension, followed later by the use of an airplane splint. In the cases where reduction of the head has been accomplished by the closed method, the period of splinting is usually about three weeks. When the head has become separated from the shaft and has had to be replaced by open operation, the period of fixation is necessarily longer in order to permit revascularization from the distal fragment to take place and union to become firm—generally from six to eight weeks. When the head has been excised the shoulder should be maintained in abduction by the method of traction and suspension for a period of about three weeks, at the end of which time massage and mobilization may be begun.

Physical therapy can be begun only after the removal of all apparatus, and follows in a general way the program previously outlined for fractures of the upper end of the humerus without displacement. Since the treatment is begun later, the response will be retarded, and the program must be guided chiefly by the progress of the patient and *accelerated only as rapidly as the gain in movement justifies. Pain is the warning signal and indicates when the treatment is being pushed too rapidly.* Avoidance of pain should be the guiding principle.

Fractures of the Shoulder Girdle.—FRACTURES OF THE CLAVICLE.—Fracture of the clavicle is a common but generally benign injury. It is encountered with the greatest frequency among children, the age period in which following injury, function is recovered rapidly. Except in the rare instances of fracture of the extreme outer tip of the clavicle, the injury does not implicate any joint. In addition, the function of the clavicle is a simple one, merely that of providing a strut to hold the shoulder outward and backward, a function that is restored by the consolidation of the fracture even with deformity. For these reasons fracture of the clavicle is rarely followed by any permanent disability.

The most common site of fracture is the middle third. Complete fractures in this region are generally accompanied by considerable deformity, the outer fragment being displaced forward, inward and downward with overriding. Reduction is readily accomplished by drawing the shoulder upward, outward and backward, and retaining it in that position. The old Sayre and Velpeau dressings proved unsatisfactory in retaining reduction and had the additional disadvantage of immobilizing the shoulder. They have now been superseded by a variety of apparatus, each of which seems to maintain the fragments in satisfactory position while leaving the shoulder joint free. From our own experience we recommend the figure-of-8 plaster bandage to both shoulders or some form of the clavicular T splint. When properly

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applied, either of these dressings maintains reduction and yet permits maximum freedom of the shoulders. In the case of women desirous of avoiding all possibility of a visible prominence at the site of the fracture, recumbent treatment may be advised for a period of two to three weeks with the shoulder fixed in wide abduction by Blake's method of traction and suspension. Nonunion is an occasional complication of fracture of the clavicle but is almost always the result of interposition of tissue and failure to obtain reduction.

With either the figure-of-8 plaster bandage or the clavicular T splint, a sling is worn for the first three or four days to support the arm, but thereafter is removed and active use of the arm and shoulder permitted. Since the shoulder is not immobilized, function is maintained, and there is no need for physical therapy. Active exercises to strengthen the muscles controlling the shoulder, upper arm and shoulder girdle may be prescribed with benefit in the convalescent stage after the splinting has been discontinued.

Fractures of the Scapula.—Fractures involving the body of the scapula are usually of the comminuted type and are associated with considerable damage to the muscles covering the scapula, namely, the supraspinatus, infraspinatus, subscapularis, teres major and minor, and the rhomboid muscles. The effects of the injury are also likely to extend to the subscapular bursa, with resulting adhesions and interference with rotation of the scapula upon the chest wall. Displacement of the fragments is limited by their muscular attachments, and the amount of bony deformity is rarely sufficient to cause limitation of function. Even with extreme deformity, it is generally impossible to correct it because of the extreme comminution. The treatment generally consists of fixation of the arm to the side by sling and circular body bandage.

Physical therapy may be started at the end of one week in the form of light superficial massage and passive mobilization. Massage should be administered, with the patient seated, to the region of the scapula, the lower neck, shoulder and upper arm. This should be followed by passive mobilization of the shoulder girdle and shoulder. Treatment may be given daily during the second week, and thereafter on alternate days. At the end of three weeks, assisted movements may be started, and active exercises may be prescribed at the end of four weeks. Applications of radiant heat may be given with benefit preceding the treatment from the end of the third week.

Recovery of function is often slow following fracture of the scapula, due to the extensive fibrotic changes in the scapular muscles, and may require three to four months. Exercises should be continued throughout this period, and the use of apparatus is often beneficial, such as wand exercises, work with the weight and pulley, golf practice, etc.

FRACTURES OF THE LOWER EXTREMITY

The functions of the lower extremity are of a highly specialized type and have to do chiefly with weight bearing and locomotion. Weight bearing necessitates the ability to support for long periods of time the constant thrust of the body weight and also of whatever additional burdens are carried by the arms, back or shoulders. When the body is in locomotion, this weight is shifted from one leg to the other and in reality sustained by one leg at a time. The functional demands upon the skeletal apparatus of the legs are therefore quite different from those made upon the arms, the former involving heavy and sustained duty and, above all, the ability to withstand end-thrust. The legs are able to support this load because their structure is admirably adapted to that end. The axes of the bones of the legs stand in nearly perpendicular relationship to the joint surfaces. The broad articular surfaces of the knee and ankle lie in the horizontal plane and are parallel to each other. The thrust is evenly distributed and is transmitted from one segment to the other with minimal strain upon the ligaments. In addition, the arched arrangement of the foot provides a tripod type of spring support which serves to cushion the weight impact with each step.

The structural relationships are so completely harmonious that any alteration produced by a skeletal fracture is likely to be attended by serious consequences. Angular deformity of the femur or tibia changes the weight distribution at the proximal and distal articulations so that one or more of the ligaments become strained, resulting sooner or later in painful function. There is uneven bearing of the joint surfaces with excessive wear at certain parts leading to degeneration of the cartilage, proliferative changes at the joint margins, and finally resulting in the characteristic picture of a localized hypertrophic or traumatic arthritis. Simple lateral displacement, provided that the axes of the fragments retain their perpendicular relationship to the joint surfaces, is much less disabling even when accompanied by a little shortening because it does not alter the direction of the weight-thrust. Shortening is unesthetic and can be avoided, but as long as this does not exceed one inch, it can be readily corrected by the addition of a small lift to the shoe, which results in little functional impairment even for heavy work.

The locomotor function requires only a moderate amount of movement of the ankle, knee and hip. In ordinary walking the knee is rarely flexed more than 45 degrees, and the arc of ankle motion rarely exceeds 10 to 15 degrees. A greater range of motion is necessary for running and for ascending or descending stairs. Stooping, kneeling and sitting call forth a still larger amount of motion in certain joints, but except for the purpose of athletic competitions the full range of possible joint movement is seldom utilized. The ordinary individual can therefore tolerate a certain degree of limitation of the

movements of the hip, knee or ankle with little functional loss; and even complete ankylosis of one of these joints, provided that it is fixed in the position of optimum function, constitutes but a small handicap.

The practical conclusion to be drawn from these observations is that in dealing with fractures of the lower extremity, preservation of skeletal alignment is more important than restoration of complete mobility. This does not mean to imply that one should not aim for full restoration of movement, but that early mobilization of the articulations should never be prescribed if it involves the slightest risk of disturbing the alignment. Fractures of the shafts of the long bones of the leg require a considerably longer period for consolidation than those of the arm, and until the union is fairly firm there is always danger of displacement. For this reason it is rarely safe to treat such injuries by massage and mobilization until consolidation is well advanced. In respect to restoring function, chief reliance must be placed upon such mobilization as may be obtained in conjunction with the traction-suspension method of treatment or upon the stimulation produced by the use of weight-bearing appliances. In general, early massage and mobilization are of chief benefit in fractures involving the ankle and knee, but even here they must be employed only with certain safeguards and limitations. It therefore follows that the rôle of physical therapy in the treatment of fractures of the lower extremity is very different from that in the upper extremity. Its use must frequently be delayed until the end-stage, when it is of small value; and in the interval, substitutes must be employed. While this is true in a general way, we must not overlook the occasional instances in which early physical therapy can be employed with advantage. Fixation of the fracture and immobilization of the joints can be just as much overdone in fractures involving the leg as in those of the arm. In applying physical therapy to the lower extremity, attention must be paid to all the joints; the foot and ankle must not be neglected when treating the knee, nor should the knee be overlooked when treating the hip. Also, greater emphasis is to be placed upon active exercises performed regularly by the patient than upon massage or passive mobilization.

Fractures of the Foot.—The arches of the foot are flexible instead of rigid structures and depend for their support upon a balanced relationship between the strength of the different groups of muscles. Normally, the inverting or supinating muscles are stronger than the everting or pronating muscles, and tests of muscle strength show a ratio of 4:3 in favor of the former. Weakening of the supinator muscles results in loss of support of the arch and pronation of the foot. Fractures of the bones of the foot disturb its function not only by alteration of its skeletal structure but also by the inevitable weakening of the muscles that results from immobilization or lack of use. When

weight bearing is resumed, the foot may pronate; and in the absence of proper support, ligamentous strain may result.

It is therefore an important matter to guard against disabilities of the foot after any bony injury of the lower extremity. Shoes of ample size and proper shape should be fitted. In the beginning, support of the arches may be necessary and may be provided by building up the inner side of the heel one-quarter inch or by fitting a padded leather insole or some other type of arch support. If there is flattening of the anterior arch, a leather metatarsal bar three-quarters of an inch wide and one-quarter inch thick may be nailed across the sole to relieve pressure upon the heads of the metatarsals, or an anterior foot cuff of leather may be employed. In addition, special foot exercises should be prescribed to strengthen the supporting muscles, the invertors and the toe flexors. A satisfactory group of exercises is as follows:

1. Standing with the feet bare, rise slowly on the toes of both feet and down again. (10 times.)
2. Stand on small platform or a thick book with the toes projecting over the end. Flex all of the toes downward strongly and return. (10 times.)
3. Sitting, cross one leg over the opposite knee and perform circular rotating movements with the foot. Plantar-flex the foot, rotate the toes inward (invert), dorsiflex the foot, rotate the toes outward (evert) and plantar-flex. (A completely circular movement should be made ten times with each foot.)
4. Roll a small towel lengthways, place it on the floor under the toes and curl the toes in plantar flexion over it, trying to grip and squeeze it. An alternative form of this exercise is to pick up a marble from the floor, grasping it with the flexed toes, lifting the leg, inverting the foot and dropping the marble in the hand of the opposite side. (Each exercise should be performed ten times with each foot.)

Fractures of the Phalanges and Metatarsals.—Fractures of a single phalanx or of one metatarsal represent simple problems and seldom result in disability. Bony deformity is often lacking, but when present should be corrected by the closed method and the part splinted with felt strips or a cardboard roll fixed with adhesive plaster and bandage. Elevation is necessary to counteract swelling. Physical therapy is not indicated in the treatment.

Multiple fractures of the phalanges and metatarsals resulting from crushing injuries are unfortunately fairly common and present more difficult problems. They are often compound and frequently necessitate the amputation of one or more toes because of circulatory impairment and gangrene. There is often gross displacement of the bones. Such injuries require treatment by continuous traction obtained either by adhesive plaster fastened to the skin of the toes or by pins or wires

movements of the hip, knee or ankle with little functional loss; and even complete ankylosis of one of these joints, provided that it is fixed in the position of optimum function, constitutes but a small handicap.

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three to six weeks. In addition, active exercises should be prescribed to mobilize the stiffened joints and develop muscular control and strength. These should include exercises for the knee and hip as well as for the foot and ankle. Progress is likely to be slow and depends a great deal upon the patient's ability to coöperate. Recovery of function in a period of six months is to be considered as an excellent result.

Fractures of the Ankle.—Fractures of the ankle present a wide variety of clinical types and occur in varying combinations of fracture of one or both malleoli, or of the articular margins, diastasis of the tibiofibular junction, and displacement of the astragalus in the outward, inward, backward or upward directions. They may be accompanied by no bony deformity or by very gross deformity. It is not within the scope of this article to discuss the classification of these injuries or to consider their surgical treatment in detail, but it is important to point out that an exact diagnosis, not only in respect to the structures involved but also as to the mechanism by which the injury was produced, is the necessary cornerstone on which to build a sound plan of treatment. We will limit our remarks to a consideration of how the treatment of ankle fractures may be aided by physical therapy. To facilitate this purpose we will divide these injuries on the basis of the presence or absence of bone deformity.

Fractures of the Ankle Without Displacement.—Many of the fractures of the ankle are accompanied by slight or no bony displacement. Such injuries are usually complete fractures, but the fracturing force has stopped short of that necessary to rupture the ligaments and the astragalus has remained in the ankle mortise. The most common injury in this group is the oblique fracture of the external malleolus resulting from external rotation of the foot.

Many of these fractures have been overtreated, and in certain instances have been kept continuously immobilized for periods of many weeks. There is no necessity for prolonged fixation, and this only leads to lengthening of the disability period. On the other hand, it is not advisable to permit active use or direct weight bearing except in the very minor sprain-fractures where small flakes of bone have been torn off by the ligaments. In such cases the ankle can be protected by an adhesive strapping and use permitted.

For the most part, however, weight bearing would result in strain at the seat of fracture and would be productive of irritation and pain. In some cases it might lead to actual displacement. The fracture should be protected by the application of a plaster casing holding the foot in a neutral position, and this should be split immediately to permit mobilizing treatment. A steel stirrup (Böhler) can frequently be incorporated in the posterior half of the plaster, and walking may be

passed through the phalanges. A plaster cast is applied from the toes to the knee with a wire hoop incorporated in the front portion, and to this the traction appliances are fixed by means of elastic rubber bands. Efforts should be made to mold the anterior arch and prevent the development of painful bony prominences on the plantar surface.

Physical therapy can rarely be employed before the end of two to three weeks, and then consists chiefly of contrast baths to stimulate the circulation and active exercises to restore flexion and extension of the toes, and to develop the muscles supporting the arch. Weight bearing in a large shoe fitted, when indicated, with a support for the anterior arch, may be permitted at the end of four to five weeks. Massage may be of service in mobilizing adherent scars, also in mobilizing the heads of the metatarsals and restoring the flexibility of the anterior arch.

Fractures of the Os Calcis and Other Tarsal Bones.—Fractures of the os calcis, astragalus or tarsal scaphoid bone are common and often permanently disabling injuries, those of the os calcis being particularly notorious for their crippling effect and having a frequency estimated as high as 2 per cent of all fractures. The treatment of each of these injuries is highly specialized and cannot be outlined in our limited space beyond emphasizing the importance of as early and complete correction of deformity as possible and of immobilization for the period necessary to obtain bony healing, usually a matter of eight weeks or more. Fixation is usually obtained by the application of a plaster casing, and because of the inadvisability of beginning physical therapy before consolidation of the fracture has occurred, it is of particular importance to make use of weight-bearing pads or stirrups in order to stimulate the circulation in some manner and to counteract bone atrophy. When the fracture involves the subastragalar or astragaloscaphoid articulations with irreparable damage to the function of these joints, an operation to ankylose one or the other of the joints may be indicated in order to get rid of a source of pain. In the case of fracture or dislocation of the astragalus, often compound, the operation of astragalectomy may be necessary.

After the removal of the splints, weight bearing is permitted in a large, easy shoe at first with the aid of crutches. In the case of fractures of the os calcis it may be advisable to apply an outside jointed brace, fixed to the shoe, for the purpose of limiting lateral mobility of the foot for a short period. If there is a tendency toward pronation of the foot, it should be prevented by the use of a Thomas heel elevated one-quarter inch on the inner side. In the beginning there is apt to be obstinate swelling of the foot, and this should be counteracted by frequent elevation of the leg, contrast bathing of the foot twice daily and the use of a woven elastic bandage. Treatment by radiant heat and massage at two-day intervals is of benefit in restoring the circulation and overcoming swelling but should not be continued for more than

patient ten to fifteen times twice daily, and during the intervals the plaster window should be replaced and fixed with straps.

The second alternative is to adopt the method of Böhler and apply an unpadded plaster casing fitted with a steel stirrup for weight bearing. This may be done either immediately after the reduction or only after the use of a padded casing for the first week or two, for the sake of safety. Walking in this plaster improves the circulation and contributes a good deal to the early restoration of function. In some instances both of these procedures may be combined.

Generally the consolidation of the fracture is sufficiently advanced by the end of four weeks to permit the daily removal of the splints and treatment of the entire part by massage and mobilization. The treatment should be given on an average of three times a week and should include both passive and assisted movements. Active exercises may be prescribed at the end of six weeks, preceded by contrast baths, and the splints may be discontinued. Unprotected weight bearing should not be permitted before the end of eight weeks; thereafter, active use and exercises are all that are needed to restore function.

Fractures of the Bones of the Leg.—Fracture of the Fibula Alone.—Fracture of the shaft of the fibula represents a minor type of injury, and we have never seen it give rise to any permanent disability. It only requires protective splinting for a week at most—the period during which unrestricted activity of the leg would be productive of pain. The displacement is unimportant and does not necessitate any attempt at reduction. It was in the treatment of this fracture that Lucas-Championnière made his trials of massage and mobilization with such brilliant results, and it is likely that the best results even now will be obtained by following his methods. Massage and mobilization may be administered from the beginning, and after one week all splinting should be discontinued. Weight bearing may be permitted at the end of two to three weeks.

Fracture of the Tibia Alone.—Fracture of the shaft of the tibia without accompanying fracture of the fibula is a much less severe injury than fracture of both bones of the leg. The intact fibula limits the amount of displacement, and after reduction is accomplished becomes a sustaining factor in helping to maintain reduction. But the very reason that makes it helpful in these two instances renders it an obstacle that must be overcome in securing reduction of a displaced fracture, since it prevents the effective use of traction in restoring alignment. When reduction is indicated, it can usually be accomplished by the closed manipulative method, but occasionally direct skeletal traction to the tibia or open reduction may be required. The alignment is usually maintained by the application of a plaster casing extending from the toes to the upper thigh.

permitted with this support when the two halves of the plaster are strapped together.

The most important part of the treatment, however, is massage and mobilization. This should begin immediately after injury and should be continued on alternate days thereafter. The massage should be of the light stroking variety and administered not only to the region of the ankle but to the foot and leg as well. It should be followed by gentle passive mobilization, and after the end of the first week assisted motion may be given. Active unassisted exercises may be started at the end of two weeks and should be performed at home twice daily, preceded by contrast bathing. Generally there is no need of any splinting protection after the end of three to four weeks, but active, unprotected weight bearing should not be permitted until the end of six weeks.

Fractures of the Ankle with Displacement.—In treating fractures of the ankle with displacement, the predominant requirement is careful reduction of the fracture with complete correction of the deformity. It may be positively stated that without complete reduction the function of the ankle will never be satisfactory. Reduction is to be sought as early as possible after injury, and can usually be accomplished by traction and manipulation with the patient anesthetized. Reduction is best maintained by the application of plaster-of-paris splints or casings. The foot should be fixed generally in the inverted position (in the case of fractures by adduction or tibial flexion in the position of eversion) and with the ankle in extreme dorsiflexion. The latter is of extreme functional importance, for dorsiflexion is recovered with great difficulty, particularly in the posterior marginal fractures; and unless the ankle is brought up into the position of right-angle flexion, or preferably above, there will always be a slight permanent equinus, and this restriction of motion is likely to be accompanied by some pain and disability on use.

The reduction of a previously displaced fracture of the ankle may readily be lost if the position of the foot is changed; therefore, it is highly dangerous to lift the ankle from the splints to permit early treatment by physical therapy. Under these circumstances one must resort to either one or another of two substitute procedures if any attempt is to be made to counteract the effects of continuous immobilization. The first is to cut out the anterior half of the plaster over the dorsum of the foot and ankle but leaving the posterior shell intact to hold the foot in the corrected position. This provides the opportunity for active movement of the foot in the directions of dorsiflexion and inversion, movements that do not endanger the reduction. The possible range of motion is small, but even a little movement is sufficient to activate the circulation, overcome swelling, restore joint flexibility and keep up muscle tone. The movements should be performed by the

deformity and permit active weight bearing. Physical therapy, consisting of radiant heat, deep stroking massage and mobilization of both the passive and assisted types, will prove beneficial at this time. They should rarely be continued for more than six weeks; after this time progress is to be obtained chiefly by use and active exercises.

Injuries in the Region of the Knee.—The quadriceps extensor muscle plays an important part in maintaining function of the knee joint through the attachment of its crureus portion to the superior prolongation of the joint capsule. The muscle has the duty of maintaining tension on the capsule and of preventing the development of relaxation folds which might interfere mechanically with joint movement. From the physiologic point of view, a healthy quadriceps muscle is a necessity for normal knee joint function. Following any injury to the knee joint, especially when immobilization is employed, there occurs a rapid and marked wasting of the quadriceps muscle. Even though healing of the injured structure is obtained, impairment of knee-joint function will persist until the normal power of the quadriceps is regained. Treatment to develop the quadriceps is of the greatest importance after any injury of the knee joint and should be continued as long as atrophy of the thigh can be demonstrated by measurement. It should begin at the earliest possible moment with quadriceps setting exercises performed 100 to 200 times a day. As soon as movement can be permitted, these should be supplemented by assisted and active motions of flexion and extension. In the convalescent stage, exercises against resistance should be prescribed, including extension of the knee against gravity, push-up exercises with the knees from the squatting position, extension against the resistance of the weight and pulley, and finally active work with the rowing machine.

Another feature to be guarded against in the treatment of injuries in or about the knee joint is stretching of the capsule from the distention of effusions, whether serous or sanguineous. Such stretching causes capsular relaxation and may be a factor in delaying recovery after healing of the injury has been obtained. It is more likely to occur in cases of chronic effusion. For this reason it is important to relieve and prevent distention by aspiration, repeated if necessary whenever joint effusion is a feature of injury. Absorption of fluid from the knee joint is also hastened by massage and mobilization (Bauer [20]). In the treatment of knee-joint injuries one should apply, when possible, the principles of relief of effusion by aspiration and early mobilization as the best means of conserving function.

Fractures of the Tibial Tuberosities.—Fractures of the upper end of the tibia extending into the knee joint have become very common owing to the prevalent height of automobile bumpers. They most frequently implicate the lateral tuberosity and may be accompanied by fractures of the upper end of the fibula or of the shaft of

The indications for physical therapy in fractures of the tibia alone are variable and depend altogether upon the amount of displacement and the security of the reduction. In fractures without displacement, massage and mobilization may be administered from the beginning; in the others, it usually has to be postponed until the end of about four weeks, when the consolidation is generally far enough advanced to permit handling the limb in safety. In the interim the weight-bearing plaster fitted with a steel walking stirrup may frequently be employed.

Radiant heat, massage, passive and active mobilization will be required for a period of about four weeks after the removal of the plaster, to stimulate the circulation and activate the muscles and joints. Active weight bearing without protection may usually be permitted at the end of eight weeks, following which there is little need for other physical therapy than active exercises to restore strength.

Fractures of Both Bones of the Legs.—The treatment of fractures of both bones of the leg often represents a difficult problem. Frequently compound, often comminuted and grossly displaced, and exhibiting a marked tendency to delayed union or nonunion, chief emphasis in the treatment of these fractures must be placed upon prevention of infection, safeguarding the soft parts from additional damage, restoration of normal alignment and obtaining bony union. Physical therapy must be relegated to a minor rôle until the apparatus can be removed with safety. Certain of these fractures can be treated successfully by the method of closed reduction and plaster fixation, but the number is small. In the comminuted and oblique fractures, alignment can be restored and maintained only by the use of direct skeletal traction with a pin or wire through the heel or lower end of the tibia, the extremity being suspended in a Thomas splint. The transverse and spiral fractures are often best treated by open reduction with fixation of the fragments by screws, plates or bands.

With reduction so difficult to obtain and maintenance of alignment so precarious, it is inadvisable to attempt early massage and mobilization. For functional stimulation of the extremity, reliance must be placed upon the use of traction and suspension instead of complete fixation, and the opportunity this affords for limited mobilization of the articulations. One must also be quick to employ weight-bearing appliances such as caliper braces and walking plasters. Consolidation may require a period of from eight to sixteen weeks or even longer, and it is only when the union is solid that massage and movement may be started. As a rule, when union is not solid by the end of eight weeks, a caliper brace, carefully fitted with a leather cuff supporting the region of fracture, should be applied. Use is the best means of stimulating the circulation and of promoting union, and such a brace will protect even a mobile fracture sufficiently to prevent

stroking massage and relaxed motion. Following reduction, the splinted extremity should be suspended in slings from an overhead frame to secure the advantages of elevation. If necessary the plaster cast can be split, the anterior half removed and the leg exposed to continuous radiant heat.

Although in the treatment of fractures with displacement physical therapy may be started at the end of three to four weeks, splinting should be continued until six to eight weeks after injury to guard against recurrence of the deformity. In the interval, treatment by radiant heat, massage, relaxed and assisted motion should be continued systematically, the hands of the technician being used to support the leg during the movements in a manner to prevent any strain at the seat of injury. After fixation of the extremity is no longer necessary, the patient should be allowed to begin to get about with the aid of the caliper brace. At this time chief emphasis should be placed upon active and resisted exercises, but massage and passive movement should be continued as long as swelling of the knee persists and knee function remains impaired—usually not longer than four months from the time of injury.

In the case of fractures that are treated in suspension and traction with early movement, massage of the knee and thigh may be administered from the start and should usually be continued on alternate days until the apparatus is removed. Mobilization should be done by the patient, but the surgeon should supervise this closely to be sure that the exercises are being performed regularly and that the range of knee motion is improving. As a rule no difficulty is experienced, the patient quickly gaining confidence and making rapid progress. The leg is left suspended in the splint for a period of four to eight weeks, depending upon the type of fracture and the degree of comminution. After the removal of the apparatus the treatment is the same as that described above for fractures with displacement.

Fractures of the Femoral Condyles.—Fractures of the condyles of the femur may be divided into two groups. The first group is made op of fractures of small fragments of bone evulsed from the medial surface of the internal condyle, or the lateral surface of the external condyle, by the pull of one of the lateral ligaments of the knee joint. The second group is composed of the severe intercondylar fractures associated with transverse fracture of the shaft of the femur in the lower third.

The first group represents fairly insignificant injuries and with proper treatment almost never results in any disability. The fracture is in reality a variant of rupture of one of the lateral ligaments, and the treatment should be modeled along the same line. A plaster casing extending from the ankle to the groin should be applied with the knee in a position of about 30 degrees flexion in order to secure relaxation of the ligament. The displacement is generally slight and

the tibia, the latter feature complicating the treatment considerably. The bony displacement usually takes the form of a depression of the lateral tuberosity, with broadening of the upper end of the tibia and the production of knock-knee deformity. The amount of displacement is variable. When the deformity is marked, it should be corrected by closed manipulation or occasionally by operation, and the reduced position maintained by the application of a plaster casing. When the amount of deformity is slight, or when owing to comminution it is of a type impossible to correct, protection and early motion constitute the chief indications. These may be met by suspension of the leg in a Thomas splint fitted with a hinged knee attachment, adhesive traction of the integral type being attached to the lower leg. A cord may be run from the end of the movable legpiece over pulleys fixed to the overhead frame until the end is within convenient reach of the patient's hand. By pulling on this cord the patient may extend or flex his knee, and thus the opportunity is provided for regular and systematic mobilization of the passive and assisted type.

One of the chief difficulties resulting from this type of fracture is lateral instability of the knee joint. This is caused by injury and relaxation of the internal lateral ligament of the knee joint, coupled with widening of the joint interspace at the outer side of the knee, resulting from failure to correct the depression of the lateral tuberosity. This not infrequently causes persistent weakness and pain in the knee joint when active use of the extremity is resumed. To prevent this disability, emphasis should be placed in the early stage upon as complete reduction as possible of the deformity with elevation of the depressed tuberosity; in the later convalescent stage, upon prolonged protection of the injured lateral ligament by the use of a brace. In addition there is need for prolonged protection of the seat of fracture, as the spongy bone of the tuberosity remains soft for a long time after the fracture has healed and may crumple down under the weight of the body. For these several reasons, a caliper brace should be fitted before the patient is allowed to be up and should be worn regularly until four to six months after injury. It should be equipped with a lock knee joint to permit flexion of the knee when sitting.

Physical therapy is a very important aid in the treatment of fractures of the tibial tuberosities. In the fractures with deformity requiring reduction, fixation of the knee joint must be enforced for a period of three to four weeks. At the end of this time the cast should be split and the extremity lifted out every day for massage of the knee, thigh and leg, and gentle passive mobilization. Prolonged fixation is unwise and almost always results in considerable limitation of motion. These fractures are frequently accompanied by severe circulatory disturbance with marked swelling and extensive bleb formation. Such cases should be treated prior to reduction by gentle

considered. If manipulation is performed, it should be done gently without any attempt to restore more than a partial range of motion; otherwise it will be followed by an excessive inflammatory reaction in the tissues about the joint that will prevent progress. Several partial manipulations at intervals of one month are better in restoring motion than one complete manipulation. Care should be taken to protect the seat of fracture by firm support under the femoral condyles. Treatment by physical therapy should be resumed beginning one to two days after the manipulation. As quickly as the patient's condition warrants, exercises on the rowing machine should be prescribed. At the end of 14 weeks, chief reliance should be placed upon active exercises, and thereafter time and active use are the chief remedies.

FRACTURES OF THE PATELLA.—The treatment of fractures of the patella varies, depending upon the type of fracture and the amount of separation of the fragments.

Fractures Without Displacement.—The patella may be fractured without separation or with only slight displacement of the fragments. The number of such injuries is small, but nevertheless it represents a definite type. The fracture may consist of a transverse or vertical crack, or it may be considerably comminuted. The lateral expansions of the quadriceps are untorn and serve as ligaments to hold the fragments together. Such fractures are usually best treated by the application of a plaster casing extending from the ankle to the groin or by a posterior splint with the knee in the position of full extension. When a casing is used it should be immediately split and the halves retained in position by straps. With such protection, weight bearing may be permitted from the beginning. Treatment by physical therapy should be started as soon as possible after injury, the splints being removed every day or on alternate days for this purpose. It should consist in the application of radiant heat, superficial massage and relaxed motion. Active exercises may be started at the end of two weeks and unprotected weight bearing at the end of four weeks.

Fractures with Separation.—The most common type of injury of the patella is the transverse fracture located at the junction of the lower and middle thirds and accompanied by considerable separation of the fragments. There may be a greater or lesser degree of comminution, and the lateral expansions of the quadriceps are severely lacerated. The best method of treatment of these fractures is by open operative repair of the torn ligaments with approximation and suture of the fragments. Without operative treatment bony union cannot be obtained, both by reason of the separation of the fragments and also because of the interposition of frayed out tendon fibers between the fractured surfaces. Preferably nonabsorbable suture material, such as fascia lata or wire, should be used to fix the fragments

reduction is not required. Weight bearing in the plaster cast may be permitted from the beginning, and no other physical therapy is needed until the splint is removed, usually at the end of about six weeks. At this time the use of radiant heat, massage, and active and resisted exercises should be begun, and active use encouraged. As a rule, there is no interruption to the rapid recovery of function.

The intercondylar T fractures of the femur are a very different class of injuries and include some of the most severe traumatisms that may be encountered. They usually result from a fall on the flexed knee. The lower end of the shaft of the femur is fractured, the end of the proximal fragment is driven into the distal one, splitting the condyles and not infrequently is pushed forward into the suprapatellar pouch and out through the quadriceps expansion, with the production of a compound wound involving the knee joint. There is extensive soft part damage and hemorrhage; the patient is in severe shock. The most skillful surgical treatment is required if his life and limb are to be saved. Under such circumstances physical therapy can have no part in the treatment until long after when the fate of the extremity has been decided, and one may begin to think of restoring function. As a matter of fact, knee stiffness of some degree is inevitable and will have to be accepted as the necessary consequence of the extensive soft part damage and scar tissue formation. The only question will be concerning the amount of motion that can be saved.

Intercondylar fractures of the femur are usually best treated by skeletal traction by means of a wire or pin passed through the upper end of the tibia at the level of the tubercle, the limb being suspended in a Thomas splint, with the knee partially flexed. Continuous heavy traction in the axis of the thigh usually brings about prompt realignment of the fragments with satisfactory restoration of the contour of the condyles. Treatment in traction and suspension must be continued for a period of at least six weeks. During the period of treatment in apparatus it is impossible to do much toward restoring knee function, although motion of the ankle and hip may be maintained. A caliper brace fitted with a lock joint at the knee should be adjusted at the end of eight weeks and weight bearing permitted.

Treatment by physical therapy can only be started when all apparatus has been removed, usually at the end of six to eight weeks. It should be applied as intensively as possible during the first three or four weeks to make up for past neglect. It should include radiant heat, light and deep massage to the calf and thigh, with special treatment of the scarred muscles, followed by passive, assisted and active motions of the knee. Careful records should be kept showing the increase of motion. If at the end of three months no marked gain is noted, the advisability of overcoming some of the adhesions by forcible passive flexion, with the patient anesthetized, should be

considered. If manipulation is performed, it should be done gently without any attempt to restore more than a partial range of motion; otherwise it will be followed by an excessive inflammatory reaction in the tissues about the joint that will prevent progress. Several partial manipulations at intervals of one month are better in restoring motion than one complete manipulation. Care should be taken to protect the seat of fracture by firm support under the femoral condyles. Treatment by physical therapy should be resumed beginning one to two days after the manipulation. As quickly as the patient's condition warrants, exercises on the rowing machine should be prescribed. At the end of 14 weeks, chief reliance should be placed upon active exercises, and thereafter time and active use are the chief remedies.

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in order to obviate the necessity of postoperative splinting. With these materials the fragments can be fixed so securely that active mobilization can be permitted immediately after operation, with considerable shortening of the disability period. When absorbable suture materials are used, the mobilizing exercises cannot be pushed as rapidly and the recovery of motion is slower.

Physical therapy is of great aid in the postoperative treatment of fractures of the patella. When osteosynthesis has been performed with fascia lata or wire, the knee should be supported by soft dressings only. During the first week no particular effort need be made toward mobilizing the knee, as the patient will do this naturally as the acute operative reaction subsides and the soreness wears away. As soon as the incision has healed, usually at the end of seven days, superficial massage can be administered, followed by passive lateral mobilization of the patella and relaxed movement of the knee. Active quadriceps setting exercises should also be prescribed. The application of radiant heat can be added at the end of two weeks, and daily active exercises of flexion and extension of the knee should be performed. Active weight bearing can be permitted at the end of four weeks, and thereafter recovery of strength and motion is chiefly dependent upon active exercises and use.

Fractures of the Shaft of the Femur.—Fractures of the shaft of the femur are extremely severe injuries, and in adults are frequently followed by some permanent impairment of function in spite of the very best treatment. In children below the age of fifteen years the results are much more favorable. There is usually extensive injury of the soft parts even though the fracture escapes being made compound. The reparative process leads to adhesion of the quadriceps extensor muscle to the callus so that the muscle becomes fixed and cannot extend with consequent restriction of the range of knee flexion. This is the common cause of the stiffness of the knee that is so frequently seen after fracture of the femoral shaft.

There is usually gross displacement of the fragments with marked overriding due to the shortening action of the powerful thigh muscles. To overcome the displacement, it is necessary to treat the fracture by continuous heavy traction, and this is usually obtained by means of skeletal tongs applied just above the femoral condyles or by a pin or wire passed through the lower end of the femur. The leg is usually suspended in a Thomas splint with the knee partially flexed on a hinged knee appliance fixed to the splint. The alternative method of treatment is by open operation with internal fixation of the fragments by a bone plate and screws or other fixative device. This method is applicable only in the transverse or oblique fractures, not in the comminuted fractures. Following operation, the leg may be splinted in a Thomas splint with light traction or in a plaster-of-paris spica casing. Consolidation of the fracture proceeds slowly and

is rarely firm before the end of seven to eight weeks, and may require considerably longer. Until union is solid the leg must be kept splinted. When weight bearing is begun, protection must be provided in the form of a caliper brace. Active use of the leg is desirable at as early a moment as possible for its stimulating effects upon the formation of callus, the circulation and muscles. The use of a caliper brace should be prescribed as a therapeutic procedure, usually at the end of eight to ten weeks.

Physical therapy has to play a secondary rôle during the active phase of treatment of a fractured femur. The necessity of securing anatomic reduction is predominant, and without this, only imperfect function can be expected. The difficulties of securing reduction and the dangers of losing position are so great that it would not be justifiable to tamper with the apparatus for the sake of attempting early mobilization of the joints. On the other hand, with treatment by traction and suspension, movement of the ankle and hip is permitted from the beginning; and when traction is obtained by means of tongs or pins fixed directly to the lower end of the femur, it is possible to begin passive mobilization of the knee at the end of three to four weeks without danger of disturbing the alignment of the fracture. In addition, the use of skeletal traction has the advantage of leaving exposed for treatment by gentle massage a large part of the surface of the limb.

For these various reasons the use of physical therapy in fractures of the femur depends chiefly upon the interest and attention of the surgeon in charge. When the fracture is treated by skeletal traction with the leg suspended in a Thomas splint, the administration of light superficial massage to the thigh and lower leg should be started at the end of two weeks. Regular active exercises of the ankle and foot may be started from the beginning. After three to four weeks, passive mobilization of the knee may be performed systematically each day within the limits permitted by the apparatus. When the fracture has been treated by osteosynthesis by means of a bone plate and screws, preference should be given to the use of traction and suspension in the after-treatment instead of a plaster spica. From the standpoint of promoting the recovery of function, the former method has great advantages and permits full benefit to be obtained from the firm operative fixation of the fracture. Massage of the thigh and lower leg, and exercise of the ankle and knee may be administered from the end of two weeks. Mobilization of the hip is obtained from the beginning by the changes in the position of the patient's body in bed. Fixation of the leg in a plaster spica, on the other hand, for the full period of eight weeks that is usually necessary, is completely destructive of function, and following the removal of the plaster a long and often painful course of mobilizing and stimulating treatment will be necessary to restore function.

Following the removal of the retentive apparatus, usually at the

end of about eight weeks, massage of the deep stroking type should be employed together with passive and assisted movement. Active exercises of flexion and extension of the knee should be prescribed and performed regularly at home by the patient. A caliper brace fitted with a lock joint at the knee, to permit flexion of the knee when sitting, should be adjusted. With the protection of the brace, weight bearing on the leg may usually be allowed at the end of ten to twelve weeks. This must usually be worn for a period of two to three months. During this time the patient should continue to work with the active exercises in order to increase the range of knee flexion, to mobilize the muscles and increase their strength. These exercises should include lying on the face, and flexing and extending the knee, sitting on the edge of a table and swinging the knee into full extension against the pull of gravity and dropping it again, and finally, of standing holding on to the back of a chair with the hands, squatting down on the heels and straightening up again. After the discontinuance of the caliper brace, the exercises of the knee may be assisted with advantage by the use of apparatus snch as the weight and pulley attached to the foot, the rowing machine or stationary bicycle. The range of knee motion increases slowly with active use over a long period and rarely reaches a complete standstill before the end of two years. In the average case, however, with adequate early functional treatment, one may expect to obtain a range of knee motion of 90 degrees by the end of six months.

Fractures of the Region of the Hip.—INTERTROCHANTERIC FRACTURES OF THE FEMUR.—Fractures of the femur between the trochanters or along the intertrochanteric line are encountered most frequently in elderly people and more commonfy in women than in men. The age factor complicates the treatment and makes it more difficult to secure complete restoration of function. The fracture itself is of a fairly benign character and because of its situation in cancellous bone, where the blood supply is abundant, presents no problem in respect to obtaining bony union. Bony deformity may be slight or well marked. It takes the form of a bending of the neck at its junction with the shaft, ascent of the greater trochanter and the production of distinct coxa vara. There is shortening of approximately one inch or more and some degree of permanent outward rotation of the leg as well.

The deformity should be corrected, and this can be readily accomplished by the application of continuous traction, the leg being suspended in a Thomas splint. Traction may be obtained by the application of adhesive plaster to the skin of the lower leg and thigh, but this involves fixation of the knee in the extended position for a period of approximately six weeks, a period quite long enough in elderly persons to occasion stiffness of the knee that is difficult to overcome. Such stiffness can be prevented by the use of skeletal

instead of adhesive traction. The danger to the patient from the insertion of Kirschner's wire in the lower end of the femur is almost negligible, and the advantage of skeletal traction in permitting regular mobilization of the knee joint is so great as to more than counterbalance the risk. A hinged knee appliance should be attached to the Thomas splint to support the lower leg, and a cord should be rigged leading over pulleys to the end of the movable leg-piece in such a way that the patient can extend or flex the knee by working the cord. Motion of the hip is obtained with the shifting of the position of the patient's body in bed, and the alignment of the fracture is not disturbed, being maintained by the constant traction force. In addition, the foot should be supported by a foot-rest, or suspended from an overhead pulley by means of an adhesive strip to the plantar surface and a small weight. Thus nearly ideal conditions are produced for maintaining joint function during the period of treatment.

The chief obstacle to carrying out the ideal method of treatment of these fractures, however, is the feeble condition of many of the patients. This makes it unsafe to employ a method that necessitates keeping the patient constantly in the dorsal recumbent position because of the danger of hypostatic pneumonia, bed sores and other difficulties. When these complications appear imminent, it is frequently the better policy to apply a plaster-of-paris spica casing, fixing the hip in a position of wide abduction and maintaining traction by means of adhesive strips applied to the leg with the free ends fixed solidly in the plaster at the level of the ankle. This method of splinting permits the patient to be turned face down as frequently as necessary to counterbalance any tendency toward hypostatic congestion of the lungs and to relieve pressure on the sacrum. The fixation of the knee, however, is likely to give rise to obstinate stiffness, and this should be combated. This may be done by employing the method described by Krida, which consists of the removal of the posterior half of the plaster from the knee to the toes as a lid. The anterior portion of the leg-piece remains attached to the spica and maintains the position of the hip. When the patient is turned face down, however, the posterior plaster shell can be removed, and this permits the knee to be flexed and extended and the ankle to be exercised. This procedure can be used at the end of two weeks when it is no longer necessary to maintain traction and the strips can be freed.

When the patient is treated by skeletal traction no formal treatment by physical therapy is indicated until after the removal of the apparatus, but the surgeon should be careful to see that the patient mobilizes the knee and ankle regularly. Union is usually solid in six to eight weeks, and at this time the splints can be removed and treatment by massage, passive and assisted movement begun. The use of a calliper brace to protect the fracture and prevent shortening is often advisable, and this should be worn for four to eight weeks. During this period the use of radiant heat, deep stroking massage, passive and

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The deformity should be corrected, and this can be readily accomplished by the application of continuous traction, the leg being suspended in a Thomas splint. Traction may be obtained by the application of adhesive plaster to the skin of the lower leg and thigh, but this involves fixation of the knee in the extended position for a period of approximately six weeks, a period quite long enough in elderly persons to occasion stiffness of the knee that is difficult to overcome. Such stiffness can be prevented by the use of skeletal

the advanced age of many of the patients. The shock of the injury, the exhausting effect of pain or of the narcotics given to relieve it, the liability to hypostatic pneumonia and pressure sores added to their frequently debilitated state create a set of conditions from which a certain number succumb in spite of the best treatment.

The method most widely advocated for securing reduction of the fracture is that originated by Whitman.[21] This consists in manipulating both hips, with the aid of traction, into a position of wide abduction and internal rotation. Anesthesia is generally necessary. Following the manipulation, the hip is fixed in the reduced position by the application of plaster of paris either in the form of a long single spica extending from the toes to the costal border or of a double spica extending on the injured side from the toes to above the pelvis and down the opposite side to the knee. The double spica secures more perfect fixation of the hip than the single spica, and at the same time makes it possible for the patient to be turned more easily and to flex the spine more readily in sitting, and for these reasons is to be preferred. It seems dangerous to apply plaster spicas to these elderly patients, but it usually proves quite the contrary in practice. The problems of handling the patient and of nursing care are greatly simplified. The patient can be moved without pain, turned regularly on the face and propped up in bed with the shoulders elevated. This counteracts any tendency to the development of hypostatic pneumonia, permits care of the back and prevents bed sores. It may prove to be a life-saving procedure in many cases.

Immobilization has to be maintained for a minimal period of twelve weeks on account of the slow process of healing. Following the removal of the plaster a caliper brace to protect the fracture and at the same time permit weight bearing must be worn for a further period of three to six months. End-result studies show that even with this long period of treatment, good results are achieved in only about sixty per cent of the cases. It is doubtful whether actual bony union is obtained in as large a number as this. These figures are disappointing, and they are stimulating surgeons throughout the world to find improved methods of treatment. Open reduction is being tried among other experiments, and the method originated by Smith-Petersen [22] of employing a flanged nail to secure internal fixation of the fracture has yielded encouraging results. It seems likely that the final word has not yet been said in respect to the best method of treatment of fractures of the neck of the femur. Until this can be spoken, however, the Whitman method still remains the accepted standard and should be applied as literally as possible.

Physical therapy cannot be employed in the treatment of fractures of the neck of the femur until at a late period because of the necessity of avoiding even the slightest motion at the hip. Passive mobilization of the knee by the method of cutting out a posterior lid from the legpiece can be started at the end of six or eight weeks. The knee should

active exercises is of aid in restoring function, but not necessary if the coöperation of the patient can be elicited in active use of the leg and in carrying out exercises.

FRACTURES OF THE NECK OF THE FEMUR.—There is scarcely a more difficult problem in surgery than that of the treatment of fractures of the neck of the femur. Although this injury is encountered chiefly in elderly women, it is not confined to that group, and examples of it may be seen in both sexes and at all ages from childhood up. There are many obstacles in the way of achieving good functional results. One of the chief ones is the difficulty of obtaining bony union. In considering this question it is important to differentiate between the fractures through the narrow part of the neck or close to the head, the so-called intracapsular fractures, and the fractures through the base of the neck, the so-called extracapsular fractures. The attempt to distinguish between these fractures on the basis of their situation in respect to the capsule is not accurate, as injury implicates the joint in both types. We prefer to use the more exact terms subcapital, transcervical and basal in describing the fractures.

The importance of the anatomic situation of the fracture lies in its relation to the blood supply to the head of the femur. In the transcervical or subcapital fractures, the blood supply to the proximal fragment is likely to be completely interrupted except for that which is conveyed through the ligamentum teres. In elderly persons the latter source is generally inadequate for nutritional needs and the head frequently dies. In addition, the neck of the femur is invested only with a covering of periosteum and synovial membrane, and enveloping soft parts from which granulation tissue may spring to aid in callus formation are lacking. Consolidation must proceed entirely from the elements within the bone and often only from those in the distal fragments. Under these conditions healing of the fracture is precarious and may fail entirely in many cases in spite of the best treatment. The only chance of obtaining bony consolidation lies in obtaining complete reduction of the fracture with close approximation of the injured surfaces and in holding the fragments firmly fixed without any movement between them for a minimal period of three months. On the other hand, in the fractures at the base of the neck the conditions are much more favorable for healing. Parts or all of the capsular ligaments through which blood supply reaches the neck of the femur remain attached to the proximal fragment, and ample nutrition is assured. In addition the adjacent soft tissues provide a source for extra osseous callus formation, which may be of great aid in bringing about consolidation. Clinical observation confirms these anatomic considerations and shows that union is obtained with great uniformity in the basal fractures, and that they present no great problem from this standpoint.

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the advanced age of many of the patients. The shock of the injury, the exhausting effect of pain or of the narcotics given to relieve it, the liability to hypostatic pneumonia and pressure sores added to their frequently debilitated state create a set of conditions from which a certain number succumb in spite of the best treatment.

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the ribs in the position of complete expiration, the shoulders droop forward, and the abdominal wall is relaxed and paunchy. This is a position of strain, and the back tires more easily than normally. Backache may or may not become evident as long as the patient remains in normal health, just as foot symptoms may be absent for long periods when the plantar arch is flat and the foot pronated. The mechanics of the spine are bad, but the individual is still able to compensate and there is satisfactory function. Compensation becomes increasingly difficult with the lapse of years, and the reserve grows smaller. The ability to compensate may be disturbed by an injury of the vertebral column or by weakening of the muscles from prolonged lack of use during the period of treatment. Recovery from the effects of the injury may be delayed by excessive strain thrown on the spine as a result of faulty attitude, or the patient may complain of pain which he attributes to the injury when in reality it is caused by postural strain, the injury itself having healed.

The longer the body has been used in a position of faulty posture, the more difficult it is to secure correction. The ligaments and muscles have adjusted themselves to the incorrect position, and the deformity has become structural instead of remaining functional. Improvement of posture can still be obtained but only at the expense of considerable effort. When function is resumed following recovery from a vertebral injury, it is important that the spinal mechanics should be as favorable as possible, and this condition can be realized only when all postural defects have been remedied. It is therefore the part of wisdom to combine postural correction with the treatment of fractures of the spine whenever possible.

When fixation of the spine is indicated, this is to be accomplished by the use of plaster shells or jackets which hold the spine as nearly as possible in the corrected position, that is, with the dorsal spine hyperextended, the lumbar spine flattened and the pelvis tilted as little as possible. When spinal braces are used, these should be fitted in such a way as to aid in postural correction. When fixation is unnecessary and recumbent treatment suffices, or in the convalescent period after the removal of retentive apparatus, a definite régime of corrective positions and exercises should be prescribed. Boards should be introduced between the springs and mattress to provide a firm, flat bed. The patient should be instructed to lie in the hyperextended position for a period of thirty minutes, two or three times a day, in order to stretch the contracted muscles and ligaments. This is a position in which the patient lies on the back with a pillow placed transversely under the scapulae and upper dorsal region and with the shoulders abducted and the hands clasped behind the neck, the knees being slightly flexed and supported by a pillow.

The following exercises should be performed with the patient recumbent:

be exercised regularly each day when the patient is turned on the face. In spite of this maneuver, however, restoring function in the injured leg presents a problem when the plaster is finally removed. The venous and lymphatic circulation are incompetent, and the leg becomes greatly edematous; the knee, often showing the effects of previous arthritis, is stiff and painful; the muscles of the thigh and leg are atrophied and weak; and the function of the hip considerably impaired. Treatment by radiant heat to the knee, massage both superficial and deep of the leg and thigh, and passive and active mobilization of the ankle, knee and hip should be administered on alternate days for a period of approximately one month after the removal of the retentive apparatus. At the end of this time the patient ought to have progressed sufficiently with walking and active use of the leg to be able to continue to improve by means of his own efforts without additional treatment.

FRACTURES OF THE SPINE

Functional Considerations.—It is of fundamental importance in the treatment of all bony injuries of the spine, regardless of their type, to strive to obtain as perfect weight-bearing alignment of the vertebral column as possible. This refers not only to securing reduction of bony deformity at the seat of fracture when this is possible, but also to stretching the spinal ligaments and developing the supporting muscles so that the fully erect posture may be assumed and maintained. The fully erect posture is to the spine what correct weight-bearing lines are to the foot. It is the position in which the weight-thrust of the body is most easily supported, and in which the least strain is thrown upon the spinal ligaments and articulations. In the fully erect posture the normal anteroposterior curves of the spine are flattened; the head is held erect in alignment with the body and with the chin pulled in; the chest is elevated in a position of moderate inspiration; the abdominal muscles are contracted firmly; and the axis of the pelvis is only slightly tipped. The balance of the body is easily maintained by the stay-like action of the psoas, recti, intercostal and scaleni muscles in front and by the glutei and sacrospinalis muscle groups behind. Lateral tilting is controlled and prevented by the action of the lateral oblique, psoas and quadratus lumborum muscles.

Unfortunately, partly as a result of the deforming pull of gravity and partly due to inattention on the part of the individual and lack of proper training, the body is rarely held in a good mechanical position; in fact, poor posture is the rule. This is characterized by an exaggeration of the normal anteroposterior curves of the vertebral column with forward inclination of the neck, rounded kyphotic deformity in the dorsal region, marked lumbar lordosis and marked tilting of the pelvis. The chin protrudes anteriorly, the chest is flat with

5. Good standing position, hands on hips, pull abdomen in; head up, stretch body tall; breathe deeply, raising chest; exhale by drawing abdomen in and up.
6. Good standing position, heels four inches from wall; hips, shoulders and head touching wall; flatten back by drawing abdomen in and up.
7. Good standing position, feet apart, weight well forward and on outside of feet, abdomen in, back flat, head up, chin in, hands clasped on top of head, elbows back, bend upper part of trunk to side; alternate.
8. Same position. Turn upper part of trunk to side; alternate.
9. Good standing position, raising arms forward upward, rise on toes; stretch tall; breathe deeply; lower arms sideward downward; lower heels; exhale.

Fractures of the Vertebral Bodies.—Fractures of the spine may be classified according to whether they involve the vertebral bodies or the accessory processes of the vertebrae such as the transverse or spinous processes or the laminae. Of these, the first group is the more serious, not only because of the possibility of an associated injury of the spinal cord, but also because the fracture menaces the weight-bearing mechanism of the spine. Injury of the spinal cord is a grave complication, and except for the few cases with partial or incomplete lesions in which recovery occurs, is accompanied by permanent paralysis of greater or lesser degree affecting all the spinal segments distal to the point of injury. Injury of the spinal cord is, however, the exception and not the rule in fractures of the vertebral bodies, contrary to what used to be taught. This has been revealed by the more frequent roentgen-ray examinations made in patients with back injuries. Studies of the late results of spinal fractures without cord injury, however, have shown that they frequently give rise to later functional impairment which may be almost as distressing from the economic point of view as paralysis is from the physical.

Fractures of the vertebral bodies are generally produced by the compression of one or more bodies between the adjacent vertebral bodies in accidents involving the transmission of force in the long axis of the spine, combined with forcible flexion of part of the spine. The most frequent site for compression fractures is the dorsolumbar junction, the point at which the relatively fixed dorsal part of the column joins with the movable lumbar portion. As a result of the compressing force, the cancellous structure of the centrum crumples, producing a wedge-shaped deformity, the body being narrower at the anterior than at the posterior border. Generally as the body is crushed, it mushrooms out and becomes broader than normal. All degrees of deformity may be encountered, varying from slight to severe. The more severe types produce definite kyphosis of the spine at the point of injury.

Treatment has for its objectives the correction of bony deformity,

1. Lying, hands at back of neck, chin in, back flat, breathe deeply, raising chest. Hold chest and exhale by drawing abdomen in and up; relax abdominal muscles to inhale.
2. Same position. Pull lower abdomen in; relax.
3. Same position. Knees bent, flatten back against floor by pulling abdominal muscles in and up.
4. Lying flat, stretch whole side, pulling ribs apart; contract side abdominal muscles; relax; alternate.
5. Same position. Hug one knee; bend other knee over chest; straighten leg; lower slowly, keeping abdominal muscles pulled in and back flat.
6. Hands on ribs. Breathe deeply, spreading ribs; hold ribs out and exhale by drawing abdomen in and up.
7. Lying face prone, hands on side, contract back muscles and raise head and shoulders from the bed.

When the patient can *sit without the necessity* of protection, the following exercises may be given:

1. Sitting tall, hands on hips, head up, chin in, back flat, breathe deeply, raising chest. Hold chest up; exhale by drawing abdomen in.
2. Same position. Hands clasped on top of head, elbows back, pull lower abdomen in; relax; repeat.
3. Same position. Stretch one whole side; relax; alternate.
4. Lie face down over edge of table, feet on floor, hands clasped in back, head back, chin in, roll shoulders back, lifting head and upper part of spine; relax; repeat.
5. Sitting tall, head up, chin in, abdomen in, back flat, hands on hips, bend upper part of trunk to side; alternate.
6. Same position. Turn upper part of trunk to side; alternate.
7. Same position. Hands clasped on top of head, elbows back, breathe deeply, pulling chest up; hold chest up; exhale by drawing abdomen in.

When convalescence is still further advanced, a combination list of exercises may be given as follows:

1. Lying, hands at back of neck, chin in, *back flat*, breathe deeply, raising chest; hold chest up and exhale by drawing abdomen in and up.
2. Same position. Knees bent, flatten back against floor by pulling abdominal muscles in and up—not a breathing exercise.
3. Same position. Hug one knee; raise other *leg* straight; lower slowly, keeping abdominal muscles pulled in and back flat.
4. *Good standing position*, feet straight ahead, weight on outside of feet, walk *forward*, abdomen pulled in, back flat, head up and back-chin in; stretch body tall.

5. Good standing position, hands on hips, pull abdomen in; head up, stretch body tall; breathe deeply, raising chest; exhale by drawing abdomen in and up.
6. Good standing position, heels four inches from wall; hips, shoulders and head touching wall; flatten back by drawing abdomen in and up.
7. Good standing position, feet apart, weight well forward and on outside of feet, abdomen in, back flat, head up, chin in, hands clasped on top of head, elbows back, bend upper part of trunk to side; alternate.
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Treatment has for its objectives the correction of bony deformity,

fixation of the spine in the corrected position during the period of healing, and finally, restoration of function. Reduction of the deformity is to be accomplished by extreme hyperextension of the spine. This may be done by forcible manipulation [23] with the patient anesthetized or gradually [24] by the use of a hyperextension frame on which the patient lies, the curve of the spine being increased from day to day. As soon as complete reduction is obtained, a plaster-of-paris jacket is applied extending from the pelvis to the axillae and maintaining the hyperextended position. With a carefully molded and close-fitting jacket, the patient may be allowed to be up and about, and the general physiology benefits from this activity. The possibility of recurrence of the deformity should be guarded against by roentgen-ray examinations from time to time. The plaster jacket should be worn for a period of about eight weeks. Following its removal, either a leather or celluloid corset or a spinal brace should be fitted and worn for an additional three to four months. This is necessary because the cancellous bone of the centrum does not solidify rapidly, and under slight strain might give way with recurrence of the deformity.

Treatment by physical therapy may be started as soon as the plaster jacket is removed. Little benefit is to be obtained from the application of radiant heat or from massage of the back because of the deep situation of the fracture in the dorsal and lumbar regions. The part of physical therapy is rather to build up and develop the muscular supports of the spine, and to lay a foundation for good spinal function by training the patient to carry his body in the erect posture. With correct treatment of fractures of the vertebral bodies beginning immediately after injury and carried through to the end, complete functional recovery may be expected. In cases where the nature of the injury is not discovered until late, and therefore in which the early treatment is inadequate, the operation of spinal fusion may be indicated later for the relief of pain.

Fractures of the Accessory Processes of the Vertebrae.—The most common fractures of the accessory processes of the vertebrae are those of the transverse processes. These are encountered almost exclusively in the lumbar region, where the transverse processes are unprotected by attachment to the ribs and are exposed to trauma. Fracture may be produced by direct trauma as from a blow in the flank or by indirect trauma acting through the muscles attached to the transverse processes, particularly the iliopsoas. One or several of the transverse processes may be fractured on the same side. Rarely the processes may be involved on both sides. The fracture may be accompanied by no displacement or by wide separation of the distal from the proximal fragment, a displacement of such degree that bony union between the fragments becomes impossible. This type of displacement is usually encountered in the cases with multiple fractures of the processes.

There is lack of agreement as to the best method of treatment of fractures of the transverse processes. Some surgeons advocate fixation of the spine by the application of plaster-of-paris jackets, while others decry the necessity of immobilization. It is our own opinion that the fracture is insignificant and that the accompanying soft part injury is the more important. There is no available means of correcting displacement of the fragments so that in the cases with wide separation where bony consolidation is bound to fail, it seems the better policy to employ treatment as for a soft part injury only. The muscular attachments to the transverse processes are so extensive that if fracture has been produced without displacement there is no likelihood of separation occurring later, and the fracture will consolidate as well without fixation as with it provided that the patient is kept quiet. As a matter of fact, observation of the late results in patients who have been treated by recumbency but without immobilization shows that they make perfect recoveries and are able to perform heavy work. We therefore favor keeping the patients recumbent for a period of four weeks but avoiding the use of retentive apparatus except when indicated by a complicating fracture of the vertebral body.

The application of radiant heat and of the superficial type of massage over the injured flank is beneficial and may be started one to two days after the injury. At the end of two weeks a régime of postural correction may be started. Active exercises should be prescribed for the abdominal, sacrospinalis and gluteal muscle groups. Additional exercises of flexion and hyperextension of the hip should be given to activate and stretch out the iliopsoas muscle, which is presumably involved in scar tissue. All movements that provoke pain should be avoided. At the end of four weeks the patient may be allowed to be up and about without protection. Standing exercises of the postural type should then be started. Recovery of function generally occurs rapidly and uneventfully. In the rare case where pain persists, particularly if there has been wide separation of one of the fragments with failure of bony union, excision of the loose fragment may be indicated.

Fractures of the spinous processes and laminae are relatively uncommon and, as a rule, must be treated on the basis of individual indications. The fractures without displacement usually require treatment by fixation for a period of about four weeks. In the case of displaced fractures it may be necessary to expose the injury by operation and to remove the loose fragment.

Fracture-Dislocations of the Cervical Spine.—The injuries of the cervical spine are much more varied than those of the dorsal and lumbar region and include dislocations, fracture-dislocations and simple fractures. It is not within our province to consider the treatment of the dislocations, which is described elsewhere. Fractures in the cervical region may be of the typical compression type with wedge-

shaped deformity of the vertebral body, but more commonly are of the fracture-dislocation type with disruption of the intervertebral cartilage and anterior displacement of the body of one vertebra upon another. The dislocation is generally accompanied by the evulsion of a triangular bony fragment from the anterior superior border of the vertebra below the seat of injury, or there may be a slight compression fracture at this point. There may also be an associated fracture of the laminae of one of the vertebrae. In addition, fracture of the odontoid process with anterior or rotary dislocation of the atlas on the axis constitutes a special type of injury. Cord injury is a much more frequent accompaniment of cervical fractures than it is of fractures in the lumbar and dorsal region. When paralysis is present it is usually of the distressing quadriplegic type, and it is almost always fatal after a longer or shorter time.

Correction of deformity is to be obtained by the application of traction to the head with the neck in the position of hyperextension. This may be accomplished gradually by continuous traction with head halter, cord, pulley and weight, or it may be done rapidly by the application of heavy traction to the head with the patient anesthetized. In either case, as soon as reduction is obtained, a plaster-of-paris jacket of the Calot type should be applied extending from the pelvis to the chin and including the occiput. This insures maintenance of correction, and with it the patient may be allowed to be up and about as soon as the general condition permits.

The jacket must usually be worn for a period of about four weeks, following which a leather Thomas collar extending from the chin to below the shoulders is fitted. This should be worn for a further period of four to eight weeks.

Treatment by physical therapy cannot be started until the end of about eight weeks from the time of injury. At this time the collar may be removed temporarily for treatment of the neck, the patient being recumbent. Baking of the neck by radiant heat, and massage of the posterior muscles of the neck are useful in preparing the way for active movements. Passive mobilization here is dangerous and should not be employed. Active lying exercises of the neck in flexion, extension, rotation and lateral flexion should be prescribed to be performed daily. These are necessary to mobilize the stiff joints and to build up the strength of the muscles so that they may support the weight of the head. The use of the collar should be discontinued gradually in proportion to the gain of strength of the neck muscles, in order to avoid fatigue. The active exercises should be continued until all weakness and discomfort have been overcome.

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CHAPTER SIX

PRINCIPLES OF PHYSICAL TREATMENT OF THE MUSCLE-TENDON SYSTEM, TENDON SHEATHS AND BURSAE

JOHN D. ELLIS, B.S., M.D.

INTRODUCTION

It is necessary, for the purposes of treatment, to think of the muscle tendon as a single organ composed of a parenchyma and a stroma. The muscle parenchyma consists of cylinders, each approximately 1½ inches long and 0.05 inch in diameter. Each cylinder has an elastic sheath of stroma—the sarcolemma. The cylinders are bound together into bundles by the perimysia interna. Larger bundles are enclosed by the coarser connective tissue septa, the perimysia externa, which, in turn, are continuous externally with the aponeurosis enclosing the entire muscle and the vaginal sheath of the muscle group. It is thus evident that the parenchyma of the muscle is enclosed in a reticulum of stroma, just as the parenchymatous organs of the abdomen are, and it is easily seen how "cirrhosis" of a muscle can occur from fibroplasia and subsequent contraction of this stroma after injury or disease. This does occur in the course of muscle healing, and it is of prime importance, in the physical therapy of the muscles, to prevent this sclerosis. All physical treatment of muscle is directed, first, toward the stroma to prevent or alleviate fibrosis, and secondly, toward stimulating the neuromuscular or vasomotor arch, which will be discussed later. It is a matter of grave doubt whether the parenchyma of the muscle can be favorably affected directly and without the intervening factor or nerve impulse by any treatment, except as this therapy mechanically removes metabolites of the muscles into the lymphatics and capillaries, brings arterial blood to the muscle cells, or removes edema or hemorrhagic accumulation. The stroma of a muscle is attached to the tendon, and, for our purpose, the tendon is simply the stroma drawn out and consolidated so that the force of the contracting muscle can be concentrated on a small area of bone. In all the muscles inserted directly into bone, without the intervention of a tendon—as, for example, in most of the axial muscles and such appendicular muscles as the deltoids and the gluteals—additional power of contraction is obtained at the expense of leverage and velocity. Mackenzie speaks of the "muscularity" of these muscles, compared with those which are largely tendinous, such as the tibialis anticus, peroneal group, and long muscles of the forearm

and fingers. The amount of "muscularity" determines the rapidity of regeneration of the parenchyma and the difficulty of reëducation after paralysis. The greater the proportion of stroma, the more the tendency to fibrous contraction of the stroma after muscle trauma or inflammation and subsequent ischemia and pressure atrophy of the parenchyma. After injury, all connective tissue displays the tendency to subsequent fibrous contraction, while parenchymatous tissue, like the muscle cylinder, tends to proliferation and regeneration with use, without displaying subsequent contraction. Carey says, "Muscle tissue (parenchyma) is a sensitive indicator, or tensiometer, recording the degree of remittent tension or work to which it is subjected." Hence, all physical treatment of muscle aims at either the prevention or alleviation of fibrosis, or the stimulation of the regeneration of muscle parenchyma by motion.

FIG. 1.—Insertion of muscle into tendon (after Mackenzie).

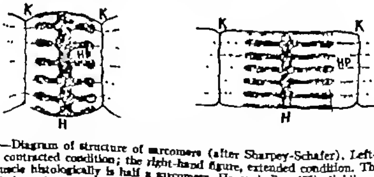

FIG. 2.—Diagram of structure of sarcomere (after Sharpey-Schafer). Left-hand figure represents contracted condition; the right-hand figure, extended condition. The functional unit of muscle histologically is half a sarcomere, Hensen's line (H) dividing a sarcomere into two independent entities. During contraction the clear material "hyaloplasm" (HP) flows into the darker "spongioplasm" (S). A sarcomere is that portion of a muscle fibril between two membranes of Krause.

The Neuromuscular Arc.—Without the work of Charles Sherrington (*completed in 1893*), we would still be speaking of the "reëducation of the paralyzed muscle," whereas we should speak of the "reëducation of the nervous arc," and while this subject encroaches somewhat on the other chapters of this system, an understanding of the basic physiology of the skeletal muscle is necessary for any discussion of remedial exercise or manipulation. The recognition that the

reëstablishment of muscle function is neurologic—not myologic—has found apt expression in a series of articles by Bankart. The mechanism of the reflex muscle arc of Sherington has thus a *practical implication* for the physical therapist. He must realize that every muscle contraction or stimulation is responsible for an afferent impulse to the cord, which is reflected out through efferent impulse to the muscle under treatment. Each time we pinch, stroke, or handle a muscle group, a stream of impulses is reflected back to the part where they were aroused, and also to the opposing muscle groups. Thus muscle stimulation is actually nerve stimulation. For clinical purposes, it seems reasonable to assume that this motor response to the stimulation of striated muscle is exhibited in two types of activity:

1. The quick, phasic and transient response seen in the execution of motion.
2. The slow, prolonged, tonic contraction, exhibited particularly by the antigravity muscles, which controls the postural activity of the muscles of the lower extremities and trunk of man, and to which Sherington applied the term "plastic tonus."

Muscle Tone.—Sherington has also shown that this postural activity starts a proprioceptive reflex which, arising in the muscle itself, is best stimulated by muscle stretching. This gives us a scientific indication for the use of muscle stretching and resisted motion in the reëstablishment of muscle tone by physical therapy after the tonus has been broken by, for example, powerful and prolonged traction on an extremity for the treatment of fracture. It furnishes argument for resisted exercise versus massage in these conditions. The theory that plastic tone is subserved by the sympathetic nerves alone is not, at present, proved to be exact. Kanavel, Pollock and Davis—and later Ransom and Hinsey—could detect no significant loss of tonus in the decerebrate animal when sympathetic denervation was performed. The importance of this mooted question to the physical therapist *is involved* in the question as to whether the caloric stimulation of a part which, it is well known, affects the vasoconstrictor apparatus, or the vasodilatory mechanism, is capable also of aiding in the reëstablishment of muscle tonus.

Muscle tone or tonus is, in the words of Sampson Wright, "one of the most misused terms in physiology, and a sharp definition is essential. It is usually defined as a state of slight, constant tension, which is characteristic of all healthy muscle and serves to obviate the muscle's taking up slack when it enters upon its contraction." But, as he points out, this explanation is inadequate, as tone is not uniformly distributed in all muscles, and the latency of toneless contraction is less than 1/100 of a second.

Decerebrate Rigidity.—Much light has been thrown upon the rationale of the prevention of contracture in paralyzed muscles and the

practical considerations to be observed in the restoration of function, by studying the mammalian preparations "decerebrated" by transection through the hind part of the midbrain. In such animals, the limbs are rigidly extended, the mouth closed, the neck in opisthotonos, while the back is arched and the tail raised. The position of the limbs is difficult to alter, and the muscles, on palpation, are firm and contracted. When placed on its legs, the animal will remain standing. This position is maintained reflexly. If the posture nerve roots coming from a limb are severed, the rigidity at once disappears from the limb. The rigidity is, therefore, reflex. If the limb is skinned, rigidity persists. It is reasonable to assume, therefore, that the afferent impulse of the reflex originates in the deep structures, i.e., the muscles, tendons, etc. If all the nerves to the muscles of an extremity, except, for instance, that to the quadriceps, are cut, only the tone in this muscle remains. This nerve to the quadriceps is, of course, a mixed one, containing both afferent fibers from special sense organs in the muscle spindles and in the tendons and motor fibers. It seems clear that the tone of a muscle depends, primarily, on impulses arising in the muscle itself. We have here a somewhat unfamiliar type of reflex whose purpose it is to maintain postural tone. We are particularly concerned with the reflex for the maintenance of position, because it affects the muscles of the extremities unequally—that is, it is manifested in those muscles which counteract gravity and prevent the animal from sinking to the ground. The muscles which are found contracted in the decerebrate preparation are termed the "antigravity" muscles. This purposive and coördinated reflex affects also the muscles antagonistic to the antigravity muscles by reciprocally inhibiting their contraction.

Decerebrate Rigidity in Man.—Decerebrate rigidity of an extremity is produced in man by brain lesions, temporary or permanent, at the same level as those produced in experimental animals, and also by unilateral or bilateral lesions of the pyramidal tracts. The practical application of splints to prevent contracture and deformity in these lesions depends on a comprehension of the distribution of these posture reflexes. While the position of the legs in man, with the knees extended and the ankles plantar flexed (extended), corresponds to the position of the hind legs in the decerebrate animal, the position of the arms is different. The arms of man, not used in locomotion, have changed in postural reflex pattern. The arms are drawn across the chest, with the forearms partially flexed. The forearms are somewhat pronated, and the wrists, thumbs and fingers are flexed. One recognizes here the position of the end-result commonly seen in hemiplegia, in which no protective splinting of the weaker muscles has been employed and no other physical therapy undertaken. This position in man is due to the release of a function of the lower brain, uninhibited by the function of the red nucleus which is concerned with the maintenance of normal body posture and normal muscle tone. It is the center for the "righting

reflexes," by means of which the body is restored to its original position after it is displaced or after loss of equilibrium. These reflexes must return before equilibrium and coördination are restored after muscle or muscle-nerve arc impairment. This is the most urgent argument for active coördinated remedial exercises in muscle and tendon rehabilitation and retraining.

Myostatic or Stretch Reflexes.—The return of normal "plastic tone" to antigravity and other muscles of the lower extremity, and to those muscles of the arm displaying this phenomenon after disease or injury of the muscle, partial or temporary damage of the reflex arc, or long and powerful traction in the treatment of fracture, can, in part, be accomplished by the stimulation of the stretch reflex. The physiology and method by which this reflex is therapeutically elicited is interesting. In the decerebrate dog, Liddell and Sherington found that a reflex response producing a contraction of 2 Kg. tension could be produced by a stretch of a few millimeters, i.e., less than one per cent of the initial length of the muscle. As the stretch is applied, rapid development of tension occurs. As an evenly applied pull is exerted, an increasing number of receptors in the muscle are successively brought into action and, reflexly, an increasing number of muscle fibers contract. While the stretch is maintained, more or less steady motor response is elicited without fatigue for as long as one-half hour. This action results in metabolic activity in the muscle and is a functional stimulation of the muscle. This type of muscle stimulation appears quite similar to the muscle rigidity of the abdominal wall reflected over the segmental representation of the innervation of the inflamed intraperitoneal viscus. It is also quite analogous to the therapeutic effect of the spasm elicited in the erector spinae muscles and the quadratus lumborum by kneading or stretching these tonically contracted muscles in an arthritic spine or a spine presenting trauma to the joint capsules and ligaments.

Had Hugh Thomas understood the sound physiologic basis upon which the practice of passive motion and manipulation now rests, he would not have uttered that pronouncement which, backed by the weight of his great prestige and authority, has retarded the development of physical treatment and, especially, scientific massage, manipulation and passive motion among the orthodox profession, even till the present time, and fostered the development of schools of peripatetic "bone setters." The full quotation of his momentous dictum is as follows:

"For many years after the commencement of my experience in surgery, I had the opportunity of observing the practice of those who had acquired a good reputation for skill as successful manipulators. I have resorted to these performances, and for many years believed that my interference assisted recovery. Long ago I have, from a more

complete knowledge, confirmed by crucial tests, so selected them that *I cannot find suitable cases upon which I would perform the deception known as passive motion.* And whereas in the early days I believed that much aid was given in recovery by passive motion, now I know by well-attested facts that some of my marvels of my past practice had been marred by the very treatment I was so proud of."

This view, from so celebrated an authority, formulated and unremittingly reiterated for the 15 years following 1875, substantiated the enduring opinion inculcated in the mind of the British regular practitioner by John Hilton's notable volume, "Rest and Pain," based on his principle of treatment by rest without massage or manipulation. He had, from 1853 to 1878, successfully and brilliantly preached a system of therapeutics in which exercise, active and passive, had no more place than massage or manipulation. The principles of Hilton and Thomas are still strongly operative in America in influencing the old-style regular practitioner against physical therapeutic measures.

The Vasomotor Reflex Arc.—Besides the conception of the muscle-neural arc as a single apparatus, a motor system, we are concerned with another reflex mechanism—the vasomotor reflex arc, which controls the supply of blood to the muscle and is impaired in efficiency in muscle subjected to accident or disease. The practical question arises as to the best means of maintaining health in a muscle which is paralyzed (the muscle-neural arcs are disturbed) until the restoration of nervous control. Suppose the efferent moiety of the arc is interrupted. In the early stages of degeneration of this paralyzed muscle, massage (which is not a stimulus to muscle repair, but a stimulus to the neural arc) cannot be expected to do anything but harm if the arc is entirely interrupted. This muscle is as much in need of rest as a fractured bone.

The question immediately arises, first, as to whether there is any satisfactory means of stimulating the vasomotor mechanism; and secondly, whether stimulation of this arc will have a beneficial effect on metabolism of the flaccid and paralyzed muscle.

Fortunately, if the vasomotor arc is intact, something can be accomplished in maintaining the metabolism of the damaged muscle until the voluntary control returns. The application of thermal stimulation aids in maintaining arterial supply and venous return in the muscle.

Physiology of the Painful Muscle.—It is, of course, common knowledge that the traumatized, inflamed muscle is painful on motion. It is the hope of the physical therapist to relieve this pain by treatment. The origin of this muscle pain is apparently twofold:

1. Spastic contraction of the peripheral arteries in certain clinical conditions is generally admitted. The clinical entity known as Raynaud's disease well illustrates this phenomenon. The exacerbations of the pain have been satisfactorily demonstrated to correspond to the

attacks of arterial spasm. Odermatt regarded spasm of the arteries as quite similar to intestinal colic. He found that sudden distention of the arterioles produced painful sensations. Where irritating substances were injected into arteries, no pain was produced unless the irritant reached the capillaries. He concluded that, under these circumstances at least, the impulses giving rise to pain arose in the capillaries and not in the larger vessels. Odermatt proved, furthermore, that painful sensations are produced by distention of arteries, regardless of their size. He believed that capillaries manifested sensibility to changes of caliber—both dilatation and contraction. Intravenous injections of salvarsan or uroselectan, as is well known, cause pain during the puncture of the vein wall and, if the wall is damaged and becomes spastic, painful sensations may persist for long periods. Stimulation of the perivascular sympathetic plexus is probably responsible for this phenomenon. However, different arteries are found clinically to respond differently to obliteration by surgical ligation. All arteries are not equally sensitive to the compression resulting from trauma. Ligation of the superior thyroid artery often causes pain radiating to the lower jaw, while ligation of the inferior thyroid is notably painless. Odermatt found that ligation of the common carotid, iliac and part of the mesenteric supply was painful. He found that some arteries which were sensitive to ligation were painful when distended. The true paths of the afferent painful impulses from the muscles are not entirely established. It seems definitely established, however, that these impulses pass through fibers connected with the posterior root ganglia of the spinal cord and are no different from sensory nerves elsewhere in the body; they simply happen to travel in the same sheaths with so-called sympathetic nerves. In the same sympathetic trunks, the efferent vasoconstrictor fibers may pass down to the vessels. Vasodilatation is probably not so simple a reaction as vasoconstriction. Lewis has convincingly demonstrated that dilator fibers may be present in the sensory nerves and not act directly on the vessel, but cause the liberation in the tissues of a histamine-like body, the "H-substance," which dilates capillaries by a direct chemical action on their muscle walls.

2. Muscle ischemia, either from vascular spasm or pressure on the blood vascular system of a muscle by edema, extravasation of blood, or the cellular products of inflammation, may cause pain on active motion. Lewis finds that pain may develop in contracting muscle, even without arterial spasm. His observations lead to the view that the stimulus causing pain is determined by some chemical or physiochemical agency within the mass of muscle. When a muscle contracts, a release of metabolites occurs within the fibers, and, obviously, these may diffuse and cause the painful stimulus. Histamine, or the "H-substance," is also liberated in injured or inflamed muscle. This may be the stimulating agent. At any event, a stimulation of the absorption by the circulation of metabolites or histamine-like substances, or the

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edematous fluid produced by trauma or by muscle action, may rectify an abnormal status of the vasoregulatory apparatus; this aids in the alleviation of pain on active motion of injured or diseased muscle. We have a satisfactory agent for the relief of vasospasm in deep heat (diathermy). The opplication of diathermy for this purpose has been recently described by de Takats. In the reëstablishment of the balance of the vasomotor arc, the approved physical treatment is "contrast baths," or the alternating application of heat and cold. Superficial and brisk skin massage, or effleurage, is reflected through the vasomotor arc to the muscle, inducing capillary dilatation of the muscle beneath, but it is doubtful if massage of the muscle itself is ever justifiable for this purpose and, in the flaccid, paralyzed muscle, probably is actively detrimental to the maintenance of vasomotor stability and metabolic activity.

Active Motion.—Muscular action of a voluntary nature comprehends a more intricate set of changes in muscle status than is usually suspected. The single action of muscular contraction on the part of one muscle or muscle group, which produces the desired effect of shortening one arm of a lever and moving a *joint* at *its fulcrum* or center of motion, is accompanied by two other types of muscle action described as antagonistic and synergic. Muscle reëducation and the reëstablishment of muscle coördination must contemplate the reëstablishment of all these types of action for every movement reëducated. When a voluntary stimulus causes one muscle *to* contract, *its* opponent muscle or group, according to the law of reciprocal innervation, is inhibited; this facilitates motion of the joint acted upon. A muscle fiber cannot be in a state of physiologic contraction and relaxation at the same time. For any muscular action exerted upon a joint, several muscle groups are involved. We may recognize those which contract, those which relax and those which steady the moving parts, as follows:

(a) The protagonists, agonists, or prime movers constitute the first class. In making a fist, the protagonists are the flexor muscles of the thumb and fingers.

(b) The antagonists constitute the second class and, in the above motion, are those which would interfere with the accomplishment of the action of the flexors, i.e., the extensors of the thumb and fingers. However, the relaxation of the antagonists is no more complete and unqualified than the contraction of the flexors. Flexion is not an unregulated action in regard to extent and force, and relaxation of the opposing extensors is essentially an active, not a passive, state. It is therefore not intended to convey the notion that the antagonists relax completely or immediately, but that there is always a nice muscle balance. In slowly accomplished motion, the antagonists react slowly and harmoniously to every nuance of motion produced by the protagonists. During violent contraction of the protagonists, they relax quickly and almost completely. In sudden action, the slack produced

by sudden relaxation is taken up by the resilience of the elastic muscle.

(c) The third class—the synergic or fixing muscles—displays an action which is secondary and designed to aid the prime movers of the joint. In clenching the fist, the synergists are the extensors of the wrist, which aid finger flexion by lengthening the rigid arm of the lever by including in it the ulna and radius. Even the triceps may contract to steady the elbow when the fist is powerfully clenched. In reëstablishing strength of motion in weakened flexor sublimis and profundus muscles, every physical therapy technician has noticed how the synergists, if uninvolved in the pathology, will tend to extend the hand at the wrist when voluntary finger flexion is attempted by the patient. This constitutes an overaction of the synergists.

Muscle Balance.—As an adaptation to physiologic need, certain groups of muscles in the human body have developed in strength of motion and resistance to fatigue out of proportion to their opposers. In the lower limb, for instance, the antigravity muscles—which are the protagonists in enabling a man to stand upright—are, in general, more powerful than their opponents, while in the shoulder, the adductors and internal rotators overshadow the abductors and external rotators. Another example is the relatively greater strength of the flexors than of the extensors of the wrist and fingers. In splinting or immobilizing a joint in a cast, the principle of muscle balance must be remembered, as it is important to put the muscle groups at rest in a position favoring the reëstablishment of motion in the weaker group as against the stronger. The joint must be flexed somewhat in the direction of the motion of the weaker group. More important still is the admonition against allowing a paralyzed joint to assume the position of contraction of the stronger group, e.g., allowing an injured shoulder to be carried in a sling in the position of adduction and internal rotation until shortening occurs in the more powerful adductors and internal rotators. More damage is done in the weaker group by allowing overstretching than in the stronger group by allowing contraction and fibrosis. Sir Robert Jones claims that in flaccid paralysis of muscle, a single lapse in the protection of the weaker group against overstretching will set back the ultimate recovery of muscle function for months.

Muscle Rest.—The position of fixation of a joint, when only one muscle or muscle group is injured, inflamed or flaccid from paralysis, constitutes an entirely different set of desiderata. The normal muscle can be considered as possessed of two functions—that of contraction and that of relaxation. During the exhibition of either of these functions, the contraction of a muscle or the relaxation of a muscle to compensate for the contraction of its opponent, a muscle may be described as being in a state of irritation. To be more technical,

Meyerhof and others have described the histologic appearance of striated muscle fibrils as consisting of an accordion-like arrangement of "spongioplasm" suspended in a more fluid "hyaloplasm" which permeates the interstices of the "spongioplasm" during relaxation and is expressed from between the folds of the accordion during contraction, both states representing a change in configuration from the resting stage.

The position of the various joints at which the opposing groups of muscles are balanced varies with the anatomy of the joint and usually coincides with the largest capacity of the joint cavity. Generally it is identical with the most useful position or the position of election for ankylosis. Thus, if we desire to put the joints and muscles producing rotation of the radio-ulnar joints at rest, a point midway between pronation and supination is chosen, while, if the knee and its flexors and extensors are to be put at rest, a position of slight flexion is desirable. However, when one set of muscles is weakened or paralyzed, it is rested when the joint is in such a position that the opposers are in a state of relaxation or elongation beyond the normal status considered to represent equilibrium for the particular joint. This is described as the "zero position" and represents the position from which it is most advantageous to begin the reëstablishment of active motion, since the minimum of muscle strength is necessary in the weakened muscle to produce the first few degrees of joint motion. A weakened muscle cannot always produce voluntary motion from a position of greatest leverage and greatest relaxation of muscle. This is exemplified in the deltoid weakened by paralysis, which initiates no abduction in the arm hanging against the side of the erect patient, but can abduct an arm beginning with the arm lying at 45 degrees' abduction with the patient in the supine position. Another example is the ability of the flaccid quadriceps femoris to flex the thigh of a patient lying on that side with the thigh already flexed a few degrees, and its inability to initiate flexion of the thigh with the patient standing and with the weight of the leg exerted against the weakened flexor. An apparently completely paralyzed muscle is often found, when tested in "zero position," to exhibit some function under circumstances calling for a minimum of tensile strength and contraction. This condition of "poverty of motion" may exist in motor paralysis of a muscle which, even by electrical tests, appears to be completely functionless. Muscle or neuromuscular arc retraining of weakened muscles of a patient floating in water takes advantage of the principle of utilizing minimum function in initiating motion by abolishing the weight of the extremity, which is suspended in a medium of practically its own specific gravity. Such methods of reëducation are now considered infinitely more effective than stimulation by electric currents or massage. Resisted motion, eliciting the stretch reflexes, and thermic stimulation to reëstablish vasomotor tone with the increasing strength of the muscle fit smoothly into this scheme of muscle rehabilitation.

Physical Treatment of Muscle-Tendon Pathology

Contusions and Sprains.—The management by physical treatment of the acutely traumatized muscle and tendon is rather universally standardized and generally accepted as consisting of rest, elevation, and the relief of edema and passive congestion. Little can be added to the general indications for treatment. The application of physical treatment to injuries of soft parts presupposes that a definite diagnosis has been made. This assumption cannot be made without complete investigation of the possibilities of underlying bone and blood-vessel injury. In 1912, Ross and Stewart provided ample experimental evidence that the ligaments have a greater tensile strength than the bony prominences to which they are attached. They showed that, when there is a so-called tear of a ligament, this takes place at the insertion of ligament into bone in the great majority of cases and that, with the tearing off of this ligament attachment, a fragment of cortex is wrenched loose. The common type of ligamentous injury, then, is a periosteal injury with the avulsion of an apophysis of bone. These ligamentous injuries are in reality "fracture-sprains," not simple sprains. The same mechanism is operative when a tendon is injured by sudden stretching, as, for instance, in falls on the extended arm, where the flexor muscles of the wrist and fingers and the extensor muscles of the elbow are forcibly stretched. Fracture is much more common than tear of ligaments or muscles, and if a muscle-tendon system is torn off, a fragment of bone at its insertion comes off with it. The indications for treatment of this "sprain-fracture" are entirely distinct from the treatment of a simple strain of muscle or tendon. X-ray diagnosis is essential here. Fractures of the greater tuberosity of the humerus are easily mistaken, if not x-rayed, for sprains about the shoulder and slight cortical avulsion. Fractures of the great trochanter tip or of the base of the fifth metatarsal, where the peroneus brevis inserts, are easily overlooked and considered, respectively, as gluteal strains or peroneus tendon sprains.

Injuries of the back are frequently dismissed from serious consideration as merely muscle contusions, and physical treatment is directed on a basis of this diagnosis. Writing on the ease with which mistakes are made in back contusions, Cohn makes several important points:

"1. The diagnosis of contusion is not justified unless everything else is eliminated.

2. Proper investigation will reveal a greater frequency of fracture of the transverse processes, incomplete fracture of the vertebral bodies and sacral injuries.

3. Early and careful examination, with detailed records of our findings, will eliminate damage suits.

4. Patients will suffer less permanent disability if their conditions are properly treated in their early stages."

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The question of the early employment, after contusion, of heat or cold depends also upon the patient's reaction. Severe angiospasm is painful, and if the application of either heat or cold, or the contrast bath of alternating heat and cold, leaves a painful extremity or muscle, it is contraindicated. In most cases, however, heat is the choice of the patient. However, it is important to note that this is not always true.

In 1917, Leriche began to make oscillometric tests on contused extremities. His associates, Flerez, Albert, and later Fontaine and Miloyevitch, have repeated and elaborated these tests. After a contusion of any part in man, the peripheral nerve endings are excited, and by reflex action the equilibrium of the vasomotor system is disturbed. These oscillometric tests prove every traumatism to be, above all, a traumatism of "vasomotoricity." The disturbance of the vasomotor equilibrium expresses itself, sometimes after a brief stage of constriction, by active vasodilatation. As a rule, these vasomotor changes are transitory and hence of no importance to the physical therapist. Sometimes, however, the disequilibrium persists, and either (1) a chronic spasm and constriction of vessels or (2) vasodilatation becomes a permanent state. Furthermore, Leriche believes that the vasodilatory state is not continuously the same, there being at the beginning a varying period of active vasodilatation with local hyperemia, followed finally by passive vasodilatory changes with cyanosis. It is difficult to analyze the reasons for this sequence or to account for it definitely on a basis of our present knowledge of the autonomic nervous system control of the caliber of blood vessels. It presupposes an active vasodilator mechanism which, as has been mentioned above, has not been satisfactorily demonstrated in man. Individual susceptibility may be the deciding factor. With Policard, Leriche has demonstrated that an atrophy of bone, as well as of muscle, occurs concomitantly with vasodilatation in the adjacent soft parts. In the first class, with beginning chronic vascular spasm, it is important to secure the return of the normal vasomotor balance by gentle massage, mechanotherapy, graded exercises and, above all, penetrating heat by diathermy. All these means of stimulating vasomotor tone may easily be overdone, and the danger is greater in too energetic than in too moderate treatment.

In the group with vasodilatory reactions, unless elevation of the part and bandaging to relieve the swelling are instituted, edema and fibrosis may ensue, like the so-called "brawny edema" of lymphatic obstruction plus infection. Leriche believes that the type with vasodilatations should be treated by the topical application of cold water, or even ice, at frequent intervals. He raises the question of the possible value of local blood-letting, an antiquated method for the relief of

Especial care must be displayed in the study of sprained and tender muscles to determine whether the trauma described by the patient was really severe enough to have resulted in the degree of tenderness, spasm and loss of motion displayed by the injured muscle-tendon system. On examination of the patient for tenderness and increased consistency of the various affected muscles, the examiner must always try to find a suitable mechanical explanation in terms of muscle function. The origin, insertion and course of the affected muscle should correspond mechanically to the probable lines of transmission and dissipation of the traumatizing force. If the subjective symptoms are too severe, or the lines of transmission of force unlikely after a given trauma, a search for other pathology than muscle-tendon injury must be made. One of the most spectacular mistakes ever made by an osteopath stands out in the mind of the writer. This occurred when he witnessed, as a medical student, the removal of a gangrenous appendix, from the tip of which protruded one-half the length of a pin. This pin had been swallowed weeks earlier and had caused severe pain and spasm of the psoas muscle, into which it had penetrated. Prior to the operative removal following the advent of gangrenous appendicitis, the patient's tender and contracted right psoas muscle had been thoroughly and conscientiously massaged and manipulated by an osteopath. A retrocecal appendicitis can easily be treated for a strained psoas muscle, and an infected kidney for a strained and spastic quadratus lumborum muscle.

Injuries of the muscles about the elbow are found to conceal a fracture of the radial head in a surprising number of cases since the advent of routine x-ray examination of injuries, and this is most important, since many of these fractures deserve immediate removal of the radial head or the offending fragments. One of the most easily confused injuries is that of transverse fracture of the scaphoid, which is commonly thought to be a sprain of ligaments or a traumatic tenosynovitis about the wrist, because the first x-ray picture does not reveal the delicate fracture line, while another view, taken a week later, after the slight absorption of the bone margins at the fracture (which constantly occurs in fractures), then allows the fracture to be seen as a radiolucent defect.

As to the use of elevation and rest by splints or light bandaging for the severely contused muscle, there is little controversy. Regarding the time, however, at which effleurage, for the purpose of dissipating the edema or products of inflammation, or deeper massage, to elicit the stretch reflexes or stimulate the vasomotor arc of the muscle, should be initiated, the opinions of different technicians vary. Some believe that passive motion or resistive exercise should almost entirely supplant massage. This probably depends on the psychology of the masseur. In general, it can be safely stated that the more ignorant the masseur, the more his tendency to damage injured muscle by deep massage during the process of healing of the damaged parenchyma.

The best guide as to the depth of massage is pain. The technician must be repeatedly warned and the patient advised that massage, to be effective and not injurious, must keep below the threshold of the pain impulse.

The question of the early employment, after contusion, of heat or cold depends also upon the patient's reaction. Severe angiospasm is painful, and if the application of either heat or cold, or the contrast bath of alternating heat and cold, leaves a painful extremity or muscle, it is contraindicated. In most cases, however, heat is the choice of the patient. However, it is important to note that this is not always true.

In 1917, Leriche began to make oscillometric tests on contused extremities. His associates, Flerez, Albert, and later Fontaine and Miloyevitch, have repeated and elaborated these tests. After a contusion of any part in man, the peripheral nerve endings are excited, and by reflex action the equilibrium of the vasomotor system is disturbed. These oscillometric tests prove every traumatism to be, above all, a traumatism of "vasomotoricity." The disturbance of the vasomotor equilibrium expresses itself, sometimes after a brief stage of constriction, by active vasodilatation. As a rule, these vasomotor changes are transitory and hence of no importance to the physical therapist. Sometimes, however, the disequilibrium persists, and either (1) a chronic spasm and constriction of vessels or (2) vasodilatation becomes a permanent state. Furthermore, Leriche believes that the vasodilatory state is not continuously the same, there being at the beginning a varying period of active vasodilatation with local hyperemia, followed finally by passive vasodilatory changes with cyanosis. It is difficult to analyze the reasons for this sequence or to account for it definitely on a basis of our present knowledge of the autonomic nervous system control of the caliber of blood vessels. It presupposes an active vasodilator mechanism which, as has been mentioned above, has not been satisfactorily demonstrated in man. Individual susceptibility may be the deciding factor. With Policard, Leriche has demonstrated that an atrophy of bone, as well as of muscle, occurs concomitantly with vasodilatation in the adjacent soft parts. In the first class, with beginning chronic vascular spasm, it is important to secure the return of the normal vasomotor balance by gentle massage, mechanotherapy, graded exercises and, above all, penetrating heat by diathermy. All these means of stimulating vasomotor tone may easily be overdone, and the danger is greater in too energetic than in too moderate treatment.

In the group with vasodilatory reactions, unless elevation of the part and bandaging to relieve the swelling are instituted, edema and fibrosis may ensue, like the so-called "brawny edema" of lymphatic obstruction plus infection. Leriche believes that the type with vasodilatations should be treated by the topical application of cold water, or even ice, at frequent intervals. He raises the question of the possible value of local blood-letting, an antiquated method for the relief of

Especial care must be displayed in the study of sprained and tender muscles to determine whether the trauma described by the patient was really severe enough to have resulted in the degree of tenderness, spasm and loss of motion displayed by the injured muscle-tendon system. On examination of the patient for tenderness and increased consistency of the various affected muscles, the examiner must always try to find a suitable mechanical explanation in terms of muscle function. The origin, insertion and course of the affected muscle should correspond mechanically to the probable lines of transmission and dissipation of the traumatizing force. If the subjective symptoms are too severe, or the lines of transmission of force unlikely after a given trauma, a search for other pathology than muscle-tendon injury must be made. One of the most spectacular mistakes ever made by an osteopath stands out in the mind of the writer. This occurred when he witnessed, as a medical student, the removal of a gangrenous appendix, from the tip of which protruded one-half the length of a pin. This pin had been swallowed weeks earlier and had caused severe pain and spasm of the psoas muscle, into which it had penetrated. Prior to the operative removal following the advent of gangrenous appendicitis, the patient's tender and contracted right psoas muscle had been thoroughly and conscientiously massaged and manipulated by an osteopath. A retrocecal appendicitis can easily be treated for a strained psoas muscle, and an infected kidney for a strained and spastic quadratus lumborum muscle.

Injuries of the muscles about the elbow are found to conceal a fracture of the radial head in a surprising number of cases since the advent of routine x-ray examination of injuries, and this is most important, since many of these fractures deserve immediate removal of the radial head or the offending fragments. One of the most easily confused injuries is that of transverse fracture of the scaphoid, which is commonly thought to be a sprain of ligaments or a traumatic tenosynovitis about the wrist, because the first x-ray picture does not reveal the delicate fracture line, while another view, taken a week later, after the slight absorption of the bone margins at the fracture (which constantly occurs in fractures), then allows the fracture to be seen as a radiolucent defect.

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Robert Jones has often pointed out, these surgeons' prejudice is based on the faulty technic of their procedure. In forcible manipulation, the following precepts are mandatory:

1. Preliminary baking, massage, and manipulation must be continued until no further improvement of function can be obtained.
2. No acute or subacute "arthritic" joint must be manipulated, or its attendant muscles forcibly stretched.
3. The muscles to be stretched must be massaged while the stretching is taking place.
4. The operation must be performed in stages.
5. At each stage, one motion only can be attempted. For instance, only the adductors of the shoulder can be stretched at one operation. Internal rotation and external rotation must be accomplished in two more separate operations.
6. Motion is continued only until adhesions about, or fibrous bands within, a single muscle or group once are felt to lengthen. Often a snap accompanies the breaking of adhesions.
7. The new position of the lengthened muscle must be maintained after each operation.
8. Heat and massage of the treated muscle must be continued until the tenderness resulting from the forcible stretching has disappeared, before another group is stretched.

By this graded method of forcible manipulation, extended over a period of several weeks, residual shortening and stiffness in contracted muscles may be alleviated. This method of manipulation should, however, be employed only after heat, massage and active and passive motion have failed fully to restore function. In contraction of the flexors or extensors of the fingers, continuous elastic traction may expedite the ordinary methods of physical therapy.

Volkmann's Ischemic Contracture

Stromeyer (1838) and Volkmann (1869) described this disastrous complication of injury and subsequent ischemia producing a flexion contracture of the fingers, wrist and forearm. This condition well exemplifies the necessity of coöperation of surgeon, physical therapist and patient in the treatment of every phase and stage in its development. Once established as an extensive degeneration and atrophy of muscle parenchyma, with fibrosis of the muscle-tendon stroma and secondary involvement of nerve trunks and joints, it challenges the most expert attempts at reconstructive surgical treatment.

The forearm is the commonest region involved, but other anatomic locations may be affected, e.g., the leg, where long muscles are encased beneath deep and unyielding layers and septa of fascia. Volkmann himself considered the contracture as due primarily to the interference with the circulation of muscle cells from tight splinting, with subse-

congestion. Later, he advises alternate local or general douches of hot and cold water, as in the hydrotherapy practiced at Aix-les-Bains.

The Rupture of Muscles and Tendons.—The rupture or partial rupture of a muscle or tendon may result from muscular violence or from a direct sharp blow on a contracted muscle or tense tendon. If the attachment to a bone is avulsed, it must, in most cases, be surgically repaired. Immediate repair of ruptured muscles and their sheaths and tendons should be undertaken before contracture of the muscle and fibrosis of the stroma have occurred. If immediate repair is not feasible, coaptation splints should be applied to the muscle belly to prevent contraction and separation of the ruptured parts, as far as this is possible. The part should furthermore be put up in the position assumed by the muscle during contraction, in order to approximate the separated parts and prevent shortening and contracture of the opposing muscle group. After repair, the muscle must be immobilized in this same position, and the application of physical treatment, except heat, is contraindicated for a period of six weeks to two months. After ten days to two weeks, however, a repaired tendon can be passively moved daily by gentle manipulation of the joint involved in its motion through an arc of a few degrees. The splint should be replaced immediately without the exhibition of any active motion. The same consideration in treatment is shown the avulsed tendon attachment, after the spicule of bone it carries has been nailed back.

The Chronic Traumatized Muscle.—The patient often presents himself for treatment after fibrosis and contracture of an injured muscle, and sometimes of its synergists, have already occurred. The question of gradual or forcible stretching presents itself. The gradual stretching of a shortened muscle is distinctly an art. The novice almost always expects results to appear too rapidly. Massage, after baking or diathermy has somewhat softened the muscle, is the routine approach. Pain, or at least discomfort, during treatment does not prevent a satisfactory progress of recovery, but an unusual amount of skill is necessary to decide what degree of pain indicates damage to the muscle. The only criterion is the question as to whether daily improvement follows any given degree of massage and stretching. In such a course of treatment, a point is often reached where no further improvement is attained or where farther motion of the adjacent joint is unbearable. Here, if one is convinced that no tuberculous or gonorrheal infection exists in the joint, and no active arthritis exists, a forcible manipulation of the joint and attendant muscles—or, rather, a series of manipulations—can be attempted. The present tendency of many capable surgeons strenuously to condemn forcible manipulation is due to their own unfortunate experience in too forcibly manipulating a stiff joint and shortened muscle groups under anesthesia. One case definitely aggravated has made them wary of this method of treatment. As Sir

The onset of symptoms, the ischemic stage, is often acute and follows the damage to the muscles within 12 hours. Before the extrinsic pressure of the splint or cast is removed, or the circulatory obstruction is relieved, the part distal to the injury becomes cyanotic or gray, cold and pulseless; edema develops and the pain is severe. Flexion of the fingers begins to appear, and attempts to correct this aggravate the pain. Removal of the cast alleviates the pain to some extent, but the swelling continues to be present for several days, though the pulse returns. The flexor pronator group now feels firm to the examining finger and may be palpably friable. Loss of power is noted in this muscle group, and skin sensation over the median or ulnar distribution may be decreased. The patient finds the hand now practically useless in grasping.

Some cases develop more gradually, with a smaller degree of pressure or obstruction on removal of a splint, or, on examining an injured arm several days after immobilization, the affected muscles are found to be firm and have started to contract. Pronation and supination are limited, and the forearm tends to pronate if the pronator radii teres is involved. Often elbow motion is limited. On removal of a cast or splint, if muscles and skin are found sloughing from pressure, the harm has been accomplished, even though no warning pain has been experienced.

Treatment.—The treatment at various stages furnishes a striking and typical example of the importance of adopting the viewpoint of muscle protection treatment during all phases of the surgical management of injured extremities. Propaganda against circular casts for the injured elbow and forearm and attempts at forcible retention of reduction or coaptation of fractures by splints has been thorough and, in general, effective. Thorough training in the surgery of injury includes inculcation of the principle of complete and anatomic reduction of fractures of the humeral condyles with early open operation, if gently applied closed methods fail. The education of every medical student must feature the dangers of any fracture treatment which leaves the part painful after reduction has been accomplished. In elbow fractures, in which the Jones position of complete flexion and supination—even if the fractures by subsequent roentgenologic check-up are seen to be perfectly reduced—leaves the elbow swollen and cyanotic, or pulseless, the complete flexion must be discontinued. Every elbow or forearm fracture or injury must be inspected at frequent intervals during the first few days for the advent of any of these dangerous symptoms of impaired circulation. In some injuries of the forearm, with or without fracture, it is wise to decompress the muscles by lateral slits through the deep fascia. It is better to employ elevation and traction until any unusual degree of swelling disappears, than to insist on immediate reduction. Hot dressings and diathermy aid in the relief of intrinsic pressure of moderate degree. Immediate

quent ischemia and ischemic necrosis. The degeneration of muscle was thought by Bardenheuer to be due to toxic necrosis as the result of venous stasis. A third explanation is that of J. J. Thomas, who believed that nerve involvement was not a complication but a necessary etiologic factor in association with ischemia and varying grades of venous obstruction. It is apparent that extrinsic pressure from the application of a tight splint, circular casts or Esmarch bandages is a common cause of the condition, but Bardenheuer found that 8 per cent of the cases occurred in fractures where no splinting or immobilization treatment was administered. Jepson, and later Lewis, demonstrated that an accumulation of blood or the advent of edema in the deep vaginal space (Prentiss) on the flexor surface of the forearm can produce ischemic contracture. Jones states that 19 out of 40 cases were associated with fracture about the elbow. Meyerding found, in 128 cases treated at the Mayo clinic, that about 5 per cent had had

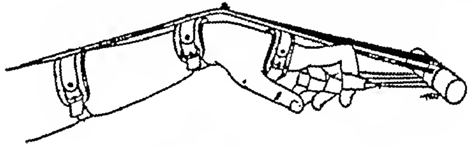

FIG. 3.—Diagram of elastic extension apparatus for early ischemic contracture.

no fracture, and that in 40 per cent of the fracture cases the humerus was involved and had been treated by the Jones method of complete supination and flexion of the elbow. This position is probably ideal when the condyles are completely reduced and not left displaced in a backward position, with the upper fragment forced into the antecubital space, cutting off the arterial blood supply and blocking the venous return. Murphy first suggested early incision by an anterolateral ulnar slit into the deep vaginal space, and Dean Lewis has repeated this.

In a few hours after compression, by either extrinsic or intrinsic pressure upon the flexor pronator group of forearm muscles, has been established, the pathologic picture of cyanosis and swelling appears. Irretrievable damage is done to the tissues within a short time. The muscles become necrotic, friable and anemic. Later, they are represented by fibrous cords, and the vessels and nerves to the forearm and hand are encased in a fibrous mass. The bones become softened, and ischemic atrophy and the atrophy of disuse develop. With the establishment of muscular contracture and rigidity, fibrous ankylosis limits the motion of the joints.

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débridement and loose closure or drainage of contaminated muscle injuries prevent deeper infection and the effects of pressure in the deep muscular compartment.

Meyerding has admirably divided the treatment of the established condition into several groups, which can be modified somewhat, as follows:

1. When the muscle damage has occurred and has been diagnosed within a few hours by the symptoms described above as the onset, abandonment of the treatment of fracture or incision of the forearm, or both, are indicated. Relief of minor grades of swelling can be obtained by skilled massage. Surface stroking (avoiding the edematous, swollen and painful area at first and gradually encroaching upon it later) is succeeded in a few days by deeper stroking and, finally, in the course of weeks, by gentle kneading. No such treatment should be followed by pain or discomfort. In the words of Mennell, "A good working law is that if pain can be relieved by massage, all is well." Active exercise in a warm whirlpool bath, followed by gentle massage, is indicated for edema resulting from contusion. Gentle traction on the fingers by means of a banjo splint or the type of finger extension splint devised by Koch, with elevation of the arm, should be employed during the periods when physical therapy is not being applied.

2. When the case is first seen several weeks after the contracture is established, incision is probably of little or no value. The hematoma or edema has now largely subsided, and fibrosis of the muscles has begun. The relief of congestion and edema by massage and whirlpool bath, and active motion is indicated. It is a matter for careful decision whether forcible manipulation to stretch the contracting muscle is desirable. After the first few weeks it is unquestionably detrimental. Traction splints with constant extension by means of elastic bands are always of considerable benefit. The traction must be gentle and not productive of pain. At whatever stage the patient comes to the surgeon, the hand should be examined for the signs of ulnar or radial nerve compression and, if this is diagnosed, an operation is immediately indicated to free the nerve from cicatrix, a neurolysis being done if necessary.

3. The next group consists of patients who present themselves with a deformity of many months' duration, in which the fingers can be straightened, or at least almost extended, with the wrist flexed, and where there is no marked degree of stiffening in the joint capsules of the fingers or wrist. Often the hand is cold and may be pulseless, and there are symptoms of nerve involvement. These patients respond less favorably to the Jones treatment of continuous extension and massage and are best operated upon, after a course of stretching and massage to restore flexibility of the muscles and increase the blood supply. The operation of choice is the Bailey operation of severing

the flexor supinator group and the pronator radii teres close to their origins and transplanting them farther down the forearm. The Max Page modification of transplanting the inner condyle, which gives origin to a large number of the fibers of the flexor-pronator group, to the inner aspect of the ulna offers a larger chance of establishing a firm, bony origin for the shortened muscles. Either of these procedures offers less chance of resulting fibrosis than an attempt at tendon lengthening in the wrist or forearm, where the tendons are already anemic and atrophied. After from one to two weeks' rest on a cock-up splint, active physical treatment must be continued to preserve the blood supply of the shortened muscles and prevent fibrosis in the new region of operative injury. Elastic traction splinting may need to be resumed. Active motion is of prime importance to preserve the neural and vasomotor arc.

4. A last group of old contractures have atrophy of the bones and ankylosed joints, as well as atrophy and fibrosis of both flexors and extensors of the wrist and fingers. The fingers cannot be straightened and yield no results from prolonged physical means of treatment. Surgery is definitely indicated here to restore somewhat the normal appearance of the hand, which may still retain a slight grasping power or some degree of opposibility of the thumb.

Spasm of Voluntary Muscles

There is a large group of cases which appear for treatment with a tendency to spasm of a muscle or muscle group. These have been divided into "functional" and "reflex" or "irritative," but at a glance it can be seen that in any particular case it is not always easy to decide that the condition is purely functional, without a reflex component. There is no doubt that a contracture may begin as a functional or occupational type, and later on impairment of the neuromuscular arc or vasomotor arc may occur from disuse of the part. According to cause, a better grouping suggests itself, as:

I. Muscle habit and occupational.
II. Reflex.
   a. Without a vasomotor imbalance.
   b. Accompanied by, or the result of, vasomotor imbalance.
III. Symptomatic of toxic, constitutional, nervous disease.
IV. Hysterical.

The first group may, in some individuals, be explained by suggestion, the habit of contraction being established as the result of a trivial trauma which causes slight pain on motion of a muscle group. Any trauma which disturbs the normal mechanism of the muscles may lead to a purely functional disability. It is difficult to draw the line between these and cases of purposeful exaggeration of slight symptoms resulting from the desire of the patient to receive com-

pensation or to substantiate a claim in common law. Apparently, the habit of contraction of a certain muscle or group at first is voluntary, but later the patient, by autosuggestion, believes that the contraction actually exists, and finally is unable to control the action of the group involved. This type of reaction can be described as conscious and unconscious malingering, the patient at first realizing that he has no disability, but later being unable to distinguish between feigned and real disability in function. This represents one of the most difficult sequels of injury arising in connection with workmen's compensation claims.

The commonest type of occupation spasm is writers' cramp. Any occupation which requires constant use or overuse of a muscle is likely to produce a similar spasm, especially if the muscles engaged in the occupation perform some highly specialized movements which necessitate elaborate coördination. Thus, it is not uncommon for writers, stenographers and watchmakers to lose the use of their hands from spasm, the muscles commonly affected being the flexor group of the fingers. A similar condition is seen in the new military recruits who come from the class of men not accustomed to much walking and who develop marchers' cramp of the feet during the early weeks of military training. The pain may be located in the calf muscles or involve the short flexor muscles of the toes. True equinovarus may develop. Physical therapy technicians develop a similar cramp in the forearm muscles. These various spasms are commonly thought by the patient to be due to a neuritis. Children practicing at the piano for long hours manifest a quite similar condition. There is always a question of the importance of the psychic element in such a child. It is easy to make a mistake in the diagnosis of spasms about the shoulder by considering these to be primary and due to occupation, when they are in reality a reflex attempt for the muscles partially to immobilize an inflamed joint or prevent motions of the shoulder which aggravate a subdeltoid bursitis.

It will be seen, then, that it is not always possible to separate reflex spasm from the first group, but in case of the former, careful examination should reveal the inflammatory lesion which is responsible for the spasm. Trauma of the muscles may set up a reflex disturbance, or it may be the starting point of an hysterical disability or lead to the establishment of a bad muscle habit of imbalance, finally resulting in permanent deformity. The actual loss of power and sensation due to the primary injury may pass off, but the reflex protective contraction of muscles which prevents movement of the injured part may persist, so that at the time of examination no evidence of the original trauma is appreciable. The reflex spasm may or may not be associated with a vasomotor imbalance. In either case, there may be a disabling pain. It is important to know whether this pain is due to pressure on a sensory nerve or not; for instance, where it is due to a tender scar on the inner side of the foot, whether fibrosis has

involved some sensory terminations, which may result in walking on the outer side of the foot with the member held in supination. With the passage of time, the pronators and external rotators of the foot become flaccid, and the supinators and internal rotators become spastic. Different types of anesthesia may develop. If there is an actual nerve lesion, the sensory distribution of the skin of the part gives the typical changes in protopathic and epicritic sensation. This aids in making a diagnosis as to the nerve involved and the level of the lesion, so that a definite indication is established for an operation to free the nerve from fibrosis. Partial lesions of the median nerve furnish the commonest example of reflex spasm and result in a serious and disabling type of pain called causalgia. The writer has seen two such spasms affecting the muscles innervated by the ulnar nerve with a painful paresthesia of the small finger and ulnar border of the hand. Anesthesia or hyperesthesia depends upon the extent of the lesion of the nerve.

There is another type in which we find an organic anesthesia, a functional change in the use of the muscles, and a loss of skin sensation may persist indefinitely. The question always arises here as to whether the disease is due to vasospasm or peripheral nerve injury. Ordinarily, in case of vasospasm, if this is of sufficiently marked degree, atrophic changes finally appear in the skin, and the part becomes blanched or cyanotic, depending on whether the lesion is principally venous or arterial. As mentioned before, the muscle, as well as the skin, is affected by these vascular changes, as determined by the experiments of Leriche. The anesthesia of vasomotor type does not, of course, correspond to any nerve distribution. There is likely to be some edema, and the skin ultimately may desquamate; or there is a loss of the hair, and the nails become deformed if the part affected is the hand or foot. The anesthesia in these cases is much like the anesthesia of disuse described by Babinski and Froment. Before the importance of the vasomotor tone in these cases was fully appreciated, these authors described the above condition as "physiopathic contracture," and Siccard called it "acromyotonus." Weir Mitchell, writing many years ago, had evidently recognized these cases as different from the ordinary muscular spasm without vasomotor involvement, which he called "paralysis from peripheral irritation." Every physical therapy technician has noted that, in treating any long-standing injury of an extremity, even when spasm or paralysis is not present to any appreciable degree, there may be a marked vasomotor disturbance, evidenced by excessive sweating in the hand or foot of the limb involved; also, that this vasomotor disturbance may appear as long as the patient's attention is called to his condition, or when he begins to discuss his injury, even before heat and massage are applied to the injured part. It is evident, therefore, that there is an autonomic imbalance in many injuries of the extremities, and this is affected by the mental state of the patient.

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involved some sensory terminations, which may result in walking on the outer side of the foot with the member held in supination. With the passage of time, the pronators and exteroal rotators of the foot become flaccid, and the supinators and internal rotators become spastic. Different types of anesthesia may develop. If there is an actual nerve lesion, the sensory distribution of the skin of the part gives the typical changes in protopathic and epicritic sensation. This aids in making a diagnosis as to the nerve involved and the level of the lesion, so that a definite indication is established for an operation to free the nerve from fibrosis. Partial lesions of the median nerve furnish the commonest example of reflex spasm and result in a serious and disabling type of pain called causalgia. The writer has seen two such spasms affecting the muscles innervated by the ulnar nerve with a painful paresthesia of the small finger and ulnar border of the hand. Anesthesia or hyperesthesia depends upon the extent of the lesion of the nerve.

There is another type in which we find an organic anesthesia, a functional change in the use of the muscles, and a loss of skin sensation may persist indefinitely. The question always arises here as to whether the disease is due to vasospasm or peripheral nerve injury. Ordinarily, in case of vasospasm, if this is of sufficiently marked degree, atrophic changes finally appear in the skin, and the part becomes blanched or cyanotic, depending on whether the lesion is principally venous or arterial. As mentioned before, the muscle, as well as the skin, is affected by these vascular changes, as determined by the experiments of Leriche. The anesthesia of vasomotor type does not, of course, correspond to any nerve distribution. There is likely to be some edema, and the skin ultimately may desquamate; or there is a loss of the hair, and the nails become deformed if the part affected is the hand or foot. The anesthesia in these cases is much like the anesthesia of disuse described by Babinski and Froment. Before the importance of the vasomotor tone in these cases was fully appreciated, these authors described the above condition as "physiopathic contracture," and Siccard called it "acromyotonus." Weir Mitchell, writing many years ago, had evidently recognized these cases as different from the ordinary muscular spasm without vasomotor involvement, which he called "paralysis from peripheral irritation." Every physical therapy technician has noted that, in treating any long-standing injury of an extremity, even when spasm or paralysis is not present to any appreciable degree, there may be a marked vasomotor disturbance, evidenced by excessive sweating in the hand or foot of the limb involved; also, that this vasomotor disturbance may appear as long as the patient's attention is called to his condition, or when he begins to discuss his injury, even before heat and massage are applied to the injured part. It is evident, therefore, that there is an autonomic imbalance in many injuries of the extremities, and this is affected by the mental state of the patient.

The spasm in these cases, while generally tonic, may also be clonic of a rhythmic or of an irregular type. The commonest form of clonic spasm is probably seen in tibialis posticus, being precipitated by weight-bearing on the ball of the foot. Evidently this muscle becomes shortened. There may even be inversion of the foot. The same clonus may be seen in the calf muscles. This clonic spasm may be a local condition, having no causal element in lesions of the central nervous system. Irregular spasm occurs when two antagonistic groups of muscles both manifest reflex spasm, the contracture of one set stretching the other, initiating a stretch reflex in the second group. When these conditions are seen in the hand, the physician commonly thinks of an hysterical etiology, but search for cause may reveal the development of a reflex spasm from injury or nerve irritation.

Symptomatic spasm of muscles may be due to tetany of various types, chorea or various diseases of the central nervous system—for instance, cerebellar disturbances, Parkinson's disease, encephalitis lethargica, disseminated sclerosis and other diseases causing rigidity of the voluntary muscles. However, these conditions must be diagnosed by many signs and symptoms in addition to spasm of the muscles. Moreover, the muscular spasm seldom affects one muscle group. They are mentioned in the present category because the general indications for treatment, so far as physical therapy is concerned, are quite similar. In addition to physical therapy, the various etiologic factors, of course, deserve therapeutic consideration. In a few instances, after cerebellar operations, prolonged physical treatment for the reëstablishment of the normal muscle tone must be undertaken. In all this group, fatigue of the muscles involved sets in more rapidly than normally, and there is actual weakness of the muscles, even though the spasm in the muscles exists.

Hysterical spasms and contractures furnish another group of these disabilities, although any of the first three groups are capable of becoming hysterical in nature, given the proper temperament and provocative "psychic trauma." The greatest difficulty connected with this group is to be certain of the diagnosis, and this requires the work of others than physical therapists. The symptoms present various unexpected contractures or hysterical attitudes, often varying from time to time when examined under varying circumstances. There is never any alteration in the reflex or any vasomotor change in the part other than a slight coldness of the extremity from lack of use. No trophic disturbances are present and no modifications of the electrical reactions of the affected muscles. The striking changes in symptoms, as a result of successful suggestion to the patient, are a notable feature. Restriction of the visual field, the history of bizarre types of convulsions which do not correspond to any organic entity, and anesthesias not based on the nerve distribution aid in making the diagnosis.

In the cases of the first and second groups, numbered I and II, muscle atrophy may appear with the relaxation of the opposing

muscles, and the affected muscles may give an exaggerated response to percussion with a hammer. The resulting contracture is large in amplitude, often delayed in the rise to its height and slower than normal to subside. After immersion in a bath of hot paraffin wax, the percussion tests reveal more normal reaction. Electrical responses are never those of the reaction of degeneration. There is an exaggerated response to faradism, unless the limb is so cold that skin resistance interferes with the passage of the current. Galvanic current stimulation produces a slow contraction of large amplitude. After the affected limb is immersed in hot water or paraffin and retested, the muscle responses are more brisk and approach the healthy muscle twitch. The amount of abnormality in response to galvanism probably depends on the proportion of vasomotor disturbances. The tendon reflexes may be slightly exaggerated or normal. In Group III, the deep reflexes of the various nervous diseases depend upon the site of the lesion. The hysterical case is notable for not presenting changed reflexes or altered reactions to faradism or galvanism diagnostic of other muscle conditions.

Treatment.—Every possible method of treatment has been suggested in these cases. Unquestionably, the most important factor in their management is, first, *to exercise to the full extent* every muscle in the limb over which the patient retains control. Since the cortical pattern of voluntary movement is not divided into muscles, but into movements, the patient must be instructed as to what movement is necessary for exercise of the affected muscle and then assisted in performing this exercise until he is able to regain some voluntary control of the spastic muscle. Gentle massage of the affected muscle is indicated, but only up to the threshold of tenderness. Gentle stroking aids in relaxing the spastic muscle preparatory to active or assistive motion. First, the application of heat or immersion in hot paraffin wax relaxes at least temporary vasospasm and allows a further motion without pain than that which could be accomplished by the patient if there were no preliminary heating of the part. The same applies to gentle massage. Surface massage, furthermore, aids in dissipation of edema where this exists. It should be remembered that, in all spasms of voluntary muscles, the point of fatigue is much lower than in normal muscles, and it is of utmost importance in all active motions to keep below the point where fatigue appears or pain develops. This entire group of disabilities presents a condition where massage alone is almost certainly doomed to failure, and where vigorous or energetic physical treatment of any sort may aggravate the condition. One of the greatest difficulties arising in connection with the reference by the surgeon to an unskilled masseur for treatment of this and other affections of muscles is the danger of too robust treatment which is certain to occur in the hands of a physical therapist whose viewpoint is that of a masseur and who has a fixed idea that he can rub

out muscle soreness. After active exercise is begun and the patient is convinced that pain on motion, tenderness and spasm are subsiding, he may develop a great enthusiasm for hastening his recovery by strenuous exercise at home between treatments. Such a situation is reprehensible, and the physical therapist will not realize the cause of the return of symptoms unless he carefully interrogates the patient as to the exact amount of exercise he takes between treatments. It is advisable to give the patient written instructions, in very specific language, as to the number of minutes of exercise he should take at home and the exact amount of motion or weight-bearing he should perform each day, and to be certain that he follows this régime punctiliously. Nothing is accomplished by attempting to hasten recovery of these patients. Any return of pain or spasm necessitates the resumption of the primary stages of treatment, consisting of baking and the gentlest massage, after which active motion can be again gradually resumed.

Occupational spasms, like writers' cramp, often require immobilization of the part on a splint, with no treatment except baking or diathermy until the weakness, tremor and lack of coördination have begun to subside. Later, the gentlest surface massage from wrist to shoulder can be applied for a few minutes a day. Mennell places great importance on the rhythmic element in massage of such an extremity, probably with the idea that each passage of the masseur's hand stimulates the rhythmic stretch reflex response and helps in the restoration of the normal coördination of muscular action. He also believes that exercise for the shoulder and elbow should be rhythmic in type, often using at first a swinging motion and later on adding pulley and roller exercises, always keeping below the point of exciting the spasm. In the management of the patient with writers' cramp, all motions can be performed except those of actual writing. Later, when writing can be performed without pain or spasm, large letters should be written on a blackboard, and, as the improvement continues, the size of the letters can be reduced until the ordinary handwriting is reproduced. The patient should be studied to see whether he uses the full-arm movement in writing or only the finger movement. If the cramp has been produced by finger-movement writing, he should be taught to write by the full-arm method.

The treatment of reflex spasm is not satisfactory unless a definite cause can be found and removed. A painful scar or sensory nerve irritation demands surgical treatment before reëducation can be started. The psychic element is sometimes important. When the patient's confidence is gained and he realizes that the pain and spasm are diminishing, recovery is tremendously expedited. Diathermy will help in dissipating vasospasm after proper surgery has been employed. There is a serious question whether routine faradic stimulation has any more effect in reëstablishing vasomotor tone or in retaining the neuromuscular arc than massage to stimulate the stretch reflexes, and

active motion to retrain the nervous arc in coördination of muscles. The paraffin bath is particularly valuable in the type accompanied by vasomotor disturbances. Sometimes the patient must be investigated for allergic phenomena and an effort made to desensitize him to the offending substance. Reëducation of muscle coördination should begin early in these cases.

It is often important not to treat the spastic part at all in the management of the hysterical case and to pay no attention to the patient's complaints. The prescription of general exercise, after explaining to the patient that you realize there is no organic basis for his disability, may yield a better result than too much attention to the affected part. The management of the psychic features is outside the function of this discussion. Fortunately, the settlement of a patient's claim for damages in an injury case is only effective in treatment of the spasm of muscles before the case has actually become hysterical and while he still realizes that he is feigning the condition. After a stage of hysteria is established, when the patient can no longer realize that the condition is not feigned, one striking method of reëstablishing his mental control of the situation is the production of full movement of the contracted part under anesthesia and the splinting of the part in the position of full movement, so that he realizes, after awakening, that such motion can be performed, and painlessly. I have had striking results with the relief of hysterical spasm of the masseter muscles by this method.

Spastic Paralysis

Cases of chronic spastic paralysis of the voluntary muscles, where contractions and flexion deformities are already established, whether from vascular lesions of the cortex or pyramidal tracts, or arrested development of upper motor neurones or their connecting links in the brain, stem or cord, present some of the most disheartening conditions the physical therapist is called upon to treat. Without the coöperation of the surgeon and physical therapist, the patient is certain to pass from bad to worse. At almost any stage of spastic paralysis, the combined efforts of the two, however, will be rewarded by some improvement.

It is important to remember that, in the motor cortex of the cerebrum, individual muscle actions are not represented, but the movement of the part is represented. This movement pattern includes both the protagonists for any motion and synergists, and the antagonists and the fixing muscles. This is the law of reciprocal innervation, and its implication, so far as treatment is concerned, is that, in retraining voluntary motion after spastic paralysis, we are retraining all these components of the motion. In brief, we are not training the man to contract any muscle, but to perform a coördinated motion. Stored in the parietal lobe are, too, the memories of various move-

ment-patterns which the patient has carried out before disease interfered with their performance, and these memories must be revived before the voluntary movement can be repeated. Furthermore, voluntary movement of the unaffected extremity may help in reestablishing the memory of the act on the opposite side. Assistive movement may help to revive this memory, which is of necessity the first step in rehabilitation. (See Vol. II.)

For purposes of treatment, the types of spastic paralysis can be divided into four groups:

1. Vascular lesions—hemorrhage, thrombosis, embolism; inflammations; new growths involving the pyramidal system anywhere in its course. These tracts may be compressed in the spinal cord from without or by a distention from within, as in the case of syringomyelia.

2. Lack of development or arrested development in the cortex—the spastic diplegia of infants, or Little's disease. Gradual death of the cells of the cortex produces spastic paralysis and an amyotrophic lateral sclerosis. Paresis of syphilitic origin affects the cerebral cortex.

3. In combined degeneration and in disseminated sclerosis, the medullary sheaths of the pyramidal fibers are destroyed.

4. Lesions in or near the corpus striatum produce Parkinson's paralysis agitans and similar conditions following encephalitis lethargica and progressive lenticular degeneration.

The management of hemiplegia, as far as its physical treatment is concerned, can be divided into stages. It is customary to say that all symptoms are present on the opposite side of the body from the brain lesion. It can be laid down as a general rule that, if any great catastrophe occurs in the central nervous system, function is disturbed even in regions remote from the structures involved. During the first few hours, we find the muscles on the opposite side from the lesion flaccid and toneless, with their deep reflexes lost. Certain regions are practically unaffected, e.g., muscles of the eyes, chest and abdomen. The paralysis then involves only the opposite arm, leg or face and spares such muscles as those of the eye, which act bilaterally, so that movement of the eyeballs and emotional expression are preserved. When this initial stage of shock subsides, spasm is found to exist in all muscles of the affected extremity, but with a difference in tone between the antigravity and the gravity muscles—in other words, since tone is concerned principally in maintenance of position or posture, the muscles involved in maintaining the erect position in man are principally affected. The affected parts tend to assume the position of decerebrate rigidity described earlier in this article. The upper limb is adducted at the shoulder, the elbow semiflexed, with the forearm pronated and the wrist and fingers flexed. These motions represent the movements of the [illegible] It is the first duty in physical treatment to prev[illegible] contraction deformities. It is important to [illegible]

for the various muscle groups, so that there is some deviation from the midposition of the joint toward the weaker group of muscles. This means, for instance, an abduction of the shoulder to protect the weak abductors and external rotators against the stronger adductors and internal rotators; the splinting of the elbow in extension or slight flexion at the midposition between pronation and supination, or with a little inclination toward supination, because supination is normally stronger than pronation. We have now accomplished the first step toward protecting the weaker muscles by establishing muscle balance and in the prevention of deformity. The position of decerebrate rigidity in the lower extremity leaves the foot plantar flexed at the ankle, with the toes flexed and sometimes with supination. These positions are corrected in the same manner.

After this primary consideration, the patient must be made to understand that the return of movement cannot be brought about by massage or electrical treatment, but by his own effort. One seldom sees a case in which some of the motor fibers are not preserved, and the management of the case contemplates preserving this minimum of muscle action and prevention of fibrosis of muscle which occurs in muscle during disuse. The patient must not lie continually in bed with his arms folded across his chest. If there is inability to perform simultaneously the various motions that constitute an act, because of the so-called decomposition of movements, some slight individual movements may be retained, and these slight voluntary movements, with the assistance of the operator, should be performed several times each day, but not to the point of fatigue. It is important that the patient make a mental effort to reproduce the motions each time treatment is given. The appearance of each new movement will be welcomed, and the patient's interest stimulated and his coöperation assured. The motions of the opposite extremity aid in the motion of the affected extremity. Rhythmic motion to music or by numbers prevents an excess of effort when the motion is performed. The reëstablishment of movement patterns in the brain may sometimes be stimulated by the application of faradic current of the sine wave form, as by minimum stimulation with a Smart-Bristow coil. After the returning movement is called to the patient's attention by this means, voluntary movement can be accomplished. Further than this, electrical stimulation has little or no place in the treatment of spastic paralysis. It is very easy to overstimulate a muscle with electricity and cause injurious fatigue, which results in more fibrosis than if no treatment had been undertaken. The patient requires special advice when he begins to walk. His natural inclination is to walk in the easiest fashion, by advancing the legs by circumduction, neglecting to flex the hips or knees, and with the foot pronated and everted. The patient should be taught to walk slightly pigeon-toed and to lift the leg with each step, even if this can be accomplished only through a few degrees of motion.

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joints. The normal muscle is already possessed of the two properties of contraction and relaxation. Relaxation immediately affects the paralyzed group, and its antagonists immediately begin to contract. Rest of a paralyzed muscle means both rest from its function of contraction and rest from its function of relaxing, which may result from contraction of its opponents. The position of muscle rest has already been described as being that position from which the reëstablishment of function is most easily begun. Rest is most suitably accomplished by splinting, the splint being frequently removed to see that no damage is done over bony points and that no constriction of the blood supply to the damaged muscle has occurred. In the

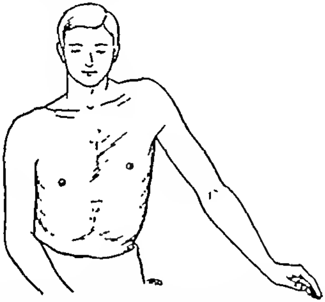


FIG. 4.—Wrong position for beginning voluntary movement of partially paralyzed deltoid. Gravity is too strong to allow any initiation of movement in the damaged muscle.

mind of every untrained masseur is the delusion that massage can restore size and strength to the damaged muscle. This is absolutely untrue. No amount of massage can restore muscle power or contour. The only effect possible is stimulation of the stretch reflex if a part of this has not been destroyed. Violent massage to the muscle belly, now deprived of its nerve supply and in some cases with the vasomotor control damaged, can only result in further insult to the blood supply in the production of edema and, later, round cell infiltration. In the early stage, these flaccid muscles are undergoing degeneration. Heat, or the alternation of heat and cold, may arouse some vasomotor response and keep the tone of the blood vessels intact. Stagnation of circulation should be prevented in some cases by elevation of the part. After a varying time, which cannot be particularized in general discussion, tests should be made to ascertain the residuum of nervous

When the patient is seen with contracture deformities already developed, the surgeon must be consulted in the management of the joints, which is covered in another chapter. If muscle-tendon groups must be lengthened, the present tendency is toward multiple incisions in the muscle at its junction with the tendon, rather than tendon lengthening operations. This is called myotomy, and has the advantage of leaving a muscle-tendon system ready for immediate massage and active motion, without the necessity of a splinting procedure to hold the part immobile until union of the repaired tendon has occurred.

In Little's disease, reëducation of the muscles is accomplished by routine gymnastic exercises where the patient follows symmetrical motions of the extremities, performed synchronously with both arms or both legs. These exercises should be done slowly. There is no advantage, but many disadvantages, in tiring the muscles or the neuromuscular control. The importance of so-called "spaced exercises," with plenty of time for rest between, has been emphasized by Sir Robert Jones.

In disseminated sclerosis and other forms of muscular atrophy which are generally classed as progressive, many cases can be improved from progression and the symptoms arrested or retarded. In the early stages, massage, muscle training and exercises may effect an apparent cure. Even if the further effects of the disease later develop, a part of the strength of the muscle fibers has been maintained and at least the opposers and synergists of the most affected muscles can be protected from the atrophy of disuse. Massage in these cases aims at maintenance of nutrition and assistance in performance of exercises. Fatigue must absolutely be avoided. The patient must be improved after each treatment, or the treatment is detrimental. The same applies to Parkinson's disease, especially the type occurring after encephalitis.

Flaccid Paralysis

The treatment of the muscles in flaccid paralysis can be divided, for clinical purposes, into (1) flaccid paralysis of nontraumatic nerve lesion and (2) the flaccid paralysis resulting from complete or partial peripheral nerve section. In the first group, it is seldom that the entire nervous control of the muscle is destroyed, and all treatment aims, in the first stages, to accomplish effective rest of the muscle, pending the time when suitable tests can be made to find what residual nervous control remains. After this initial stage of treatment, attempt is made to preserve the function of these neuromuscular arcs which remain and to develop whatever residual nervous control has escaped the damage of the nerve lesion. Effective rest of the muscles should begin immediately at the time the paralysis develops. This will minimize the necessity for operative interference or leave the limb in the best possible condition for whatever operation may be necessary, whether this be transplantation of tendons or stabilizing operations on the

Bristow coil, may reëducate the voluntary cerebral control so that the patient is soon able to produce this slight muscle movement himself. Passive movement through a part of the arc of the motion to be reëstablished may aid in eliciting the memory of the motion. Massage is now available to relax the opposers prior to each treatment. The active treatment, however, consists of training the patient

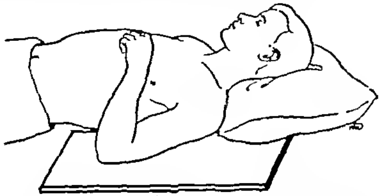


FIG. 6.—Position for beginning voluntary motion of paralyzed deltoid.

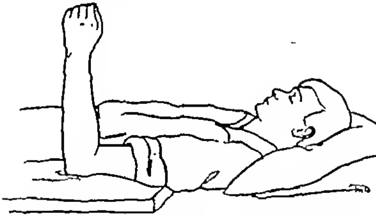


FIG. 7.—Commencing voluntary pronation. Forearm has the minimum resistance of weight in this balanced position.

in voluntary motion. Such massage should be slow and even, the stroking firm and combined with gradual stretching of the contracted antagonists. Little massage is necessary over the flaccid muscle. Passive manipulation of the joint prevents contraction until the patient learns to use the paralyzed part. No flaccid paralyzed muscle should ever be allowed to stretch by passive motion of the joint. One treatment involving thorough stretching of such a damaged muscle means that the whole task of retraining must be started over again. Another warning should be given against overfatigue. If the patient can move

control. *There is only one true test for muscular action, and that is the volitional test.* We must consider the effect of gravity in interfering with the slight motion of a weakened muscle. To obviate the weight of the part, it could be suspended in water and the amount of muscle regeneration tested by having the patient move the extremity, which now, with the patient in the bath, has no weight, being of the same specific gravity approximately as the water bath. Another method is to begin motion from the most advantageous position, with the part lying on a smooth surface—for instance, cardboard to which talcum has been applied. One example will illustrate the principle: the paralyzed quadriceps femoris group in a child with anterior poliomyelitis, after the infective stage of the disease is past;

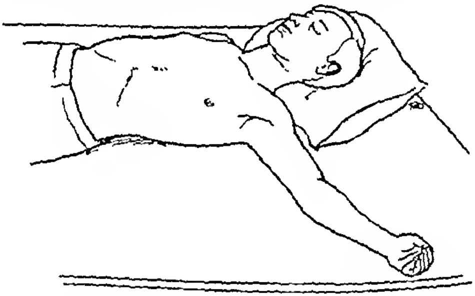


FIG. 4.—Patient able to abduct arm when force of gravity is relieved.

the child, sitting in a chair, may not be able to raise the knee because gravity is too strong for the initiation of movement in this damaged muscle group. However, the child lying down, the knee and hip already being in the position of semiflexion, a slight further flexion of the hip can be produced voluntarily. This applies equally well to the shoulder muscles and muscles of the arm. Should contraction of the antagonistic uninjured muscles have been allowed to occur through neglect of treatment of the first stage, even this test may show no muscle action, although a slight voluntary control still exists. After massage and stretching of the unaffected opposers, a slight muscle action of the quadriceps may be found to remain. To my mind, the only use of electricity indicated is to aid in restoring the memory of voluntary action of a muscle too far damaged to present any evidence of nervous control with the above tests. Often small doses of faradic electricity of the sine type, produced with the Smart-

Bristow coil, may reëducate the voluntary cerebral control so that the patient is soon able to produce this slight muscle movement himself. Passive movement through a part of the arc of the motion to be reëstablished may aid in eliciting the memory of the motion. Massage is now available to relax the opposers prior to each treatment. The active treatment, however, consists of training the patient

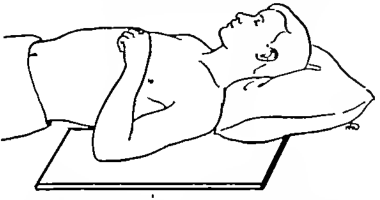


FIG. 6.—Position for beginning voluntary motion of paralyzed deltoid.

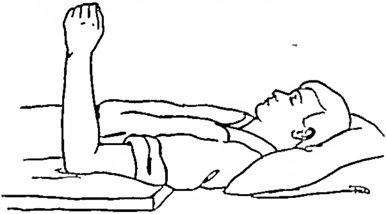


FIG. 7.—Commencing voluntary pronation. Forearm has the minimum resistance of weight in this balanced position.

in voluntary motion. Such massage should be slow and even, the stroking firm and combined with gradual stretching of the contracted antagonists. Little massage is necessary over the flaccid muscle. Passive manipulation of the joint prevents contraction until the patient learns to use the paralyzed part. No flaccid paralyzed muscle should ever be allowed to stretch by passive motion of the joint. One treatment involving thorough stretching of such a damaged muscle means that the whole task of retraining must be started over again. Another warning should be given against overfatigue. If the patient can move

the muscle in spaced exercises, only five or six actions of the injured muscle should be attempted in four or five treatments during each day. This is more valuable than pushing the return of motion by more violent action. If, on any given day, it is found that exercise cannot be performed with as much freedom as on the day previous, the treatment is being pushed too energetically, and the muscles should be maintained at rest by splinting for two or three days. Then the exercises can be gradually resumed.

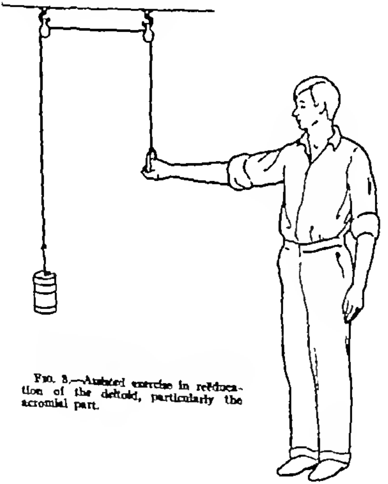


FIG. 8.—Assisted exercise in reëducation of the deltoid, particularly the acromial part.

It is not important for our purpose to distinguish between various types of flaccid paralysis due to disseminated changes in the central nervous system and so-called primary diseases of the muscle, like myasthenia gravis, which are progressive and may be called flaccid types of paralysis. In all these conditions, the tone and strength of the unaffected muscle must be maintained, deformity must be prevented, and, in some, the slow deterioration of the muscles affected may be delayed by the minimum amount of active exercises of the muscle group, also keeping below the threshold of fatigue.

As strength returns in a muscle through training, *assistive exercises* may be employed, the operator bearing most of the weight of the part—that is, allowing motion with the minimum of effort on the part of the patient. Assistive exercises with weights and pulleys are also serviceable. Retraining in walking is covered in a separate article in this system (Molander, Vol. III).

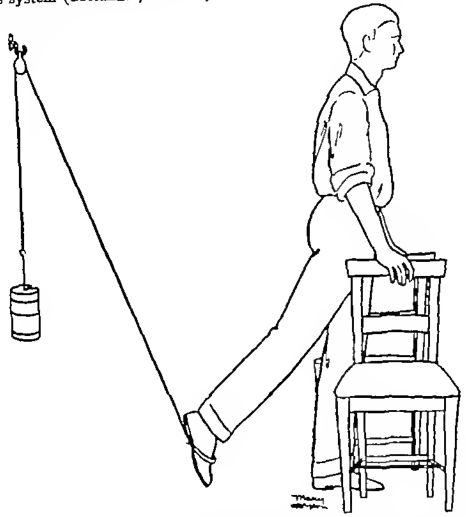


FIG. 9.—Earliest resistive exercise of the weakened quadriceps femoris group. This is the same position as employed for assistive exercise of the flexors of the hip.

Paralysis from Severed Nerves.—If the nerve is only partly severed, treatment is not so different from that described for flaccid paralysis in central nervous lesions. When the nerve is completely severed, early massage is indicated to minimize the scar tissue of the original injury, which may involve the muscle as well as the nerve. When the patient attempts to move the part, many unusual antagonistic movements may result, as the impulse is not directed to the

movement of the muscle but to the performance of the motion. While the part is splinted during the treatment of the laceration itself or the treatment of infection, gentle massage may preserve the vasomotor tone of the flaccid muscles, and, as no faradic response is elicited, the sine current of galvanism may aid in preserving the vasomotor reflexes, if these do not all reach the muscle along with the severed nerve. If a nerve is severed near the shoulder or hip, a part of the

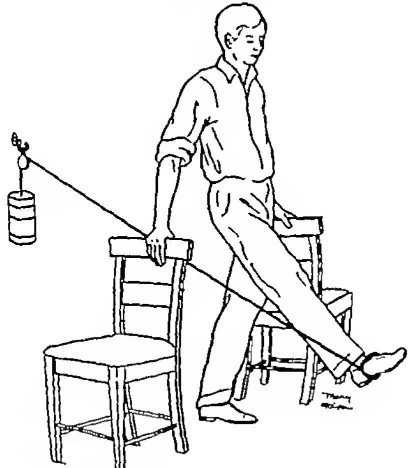


FIG. 10.—Later position in treatment of weakened extensors of the knee and flexors of the hip.

vasomotor reflex reaches the affected muscle from the autonomic fibers traveling along the main arteries of the part, while others travel in the same sheath with the injured peripheral nerve.

After surgical repair of the severed nerve, if the operation is successful, faradic response gradually appears in the muscle. Faradic treatment has as its only importance, reëducation of the voluntary control of the muscle. It is easy to overdo this faradic stimulation. Only a few contractions of the muscles daily by this method should

be attempted. After the habit pattern is reëstablished in the brain, the patient is able voluntarily to perform a minimum of motion under the type of management just described for the flaccid paralysis of central nervous diseases.

In a recapitulation of this subject, Mennell has laid down certain principles which are briefly as follows:

1. An enfeebled muscle cannot contract unless and until its antagonist relaxes in conformity.

2. To make sure that the patient's muscles know how to perform the movement, the sound limb should be put through the same movement which we expect to reëducate in the injured extremity.

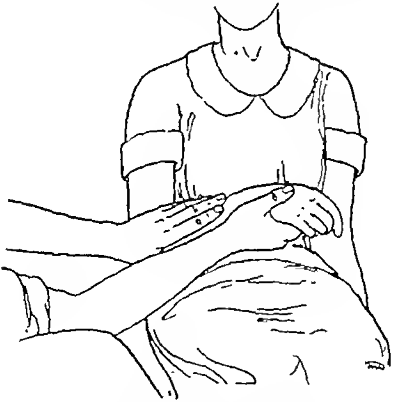


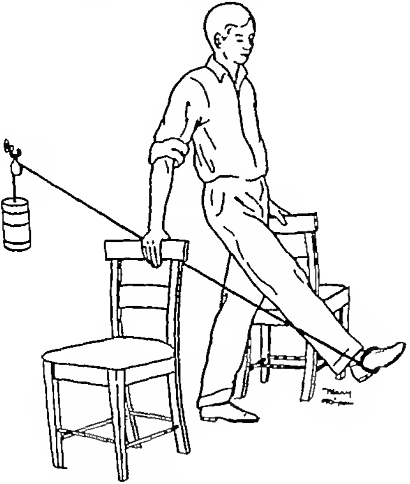
FIG. 11.—Position for manually assisted supination.

3. In muscle reëducation, we must not set a task for the muscle more difficult than it can perform at any given stage in regeneration.

4. As one type of motion is accomplished, a second should be devised, each entailing imperceptibly greater coördination than the previous one.

5. Mackenzie has pointed out that it is best to begin with retraining of the specific functions of each muscle and to add concerted

movement of the muscle but to the performance of the motion. While the part is splinted during the treatment of the laceration itself or the treatment of infection, gentle massage may preserve the vasomotor tone of the flaccid muscles, and, as no faradic response is elicited, the sine current of galvanism may aid in preserving the vasomotor reflexes, if these do not all reach the muscle along with the severed nerve. If a nerve is severed near the shoulder or hip, a part of the



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actions later. He believes that each muscle normally has one specific action.

6. Submaximal effort should be repeated frequently a few times a day, and the maximum effort less frequently, if at all.

7. The enfeebled muscle must never be stretched.

8. If, on any day, the patient is found not able to perform as much motion as on the previous day, the task should be lightened for a few days.

9. An atrophy from disuse is as hard, or harder, to cure than atrophy from disease. Nothing must be done which interferes with the blood supply or delays the venous drainage of the part.

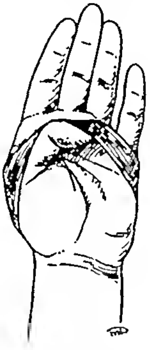

FIG. 14.—Application of adhesive strap to protect paralyzed flexor system of thumb (median paralysis).

Inflammations of Muscles

Myalgia (Muscular Rheumatism).—This term refers practically to all cases of inflammations of the muscles and their attachments, with the accompanying spasm and pain on motion. The treatment of this affection of the muscles, in its acute stage, is familiar to all physicians engaged in physical treatment and is more thoroughly covered in the volume of this series devoted to internal medicine. The treatment of acute rheumatic affections is, in a large part, constitutional, the physical means applied to the affected muscles being only palliative. Hydrotherapy, for the purpose of stimulating the blood

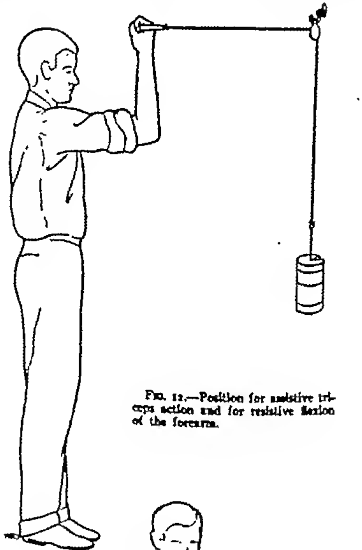

FIG. 12.—Position for assistive triceps action and for resistive flexion of the forearm.

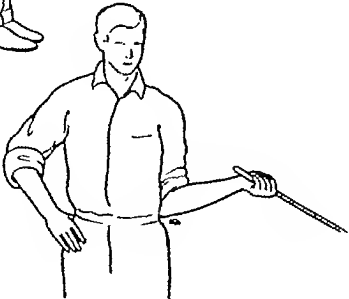

FIG. 13.—Assistive supination by means of weight (a poker).

actions later. He believes that each muscle normally has one specific action.

6. Submaximal effort should be repeated frequently a few times a day, and the maximum effort less frequently, if at all.

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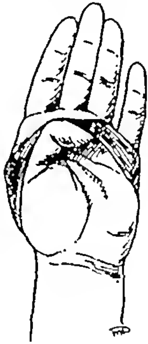

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supply, and the use of various baking apparatus need no description here.

Pemberton thinks that the physiologic background of the problem of derangement of muscle function in these affections probably has to do with an alteration in the "finer blood supply." Microscopic study of the capillary beds shows various irregularities with decrease

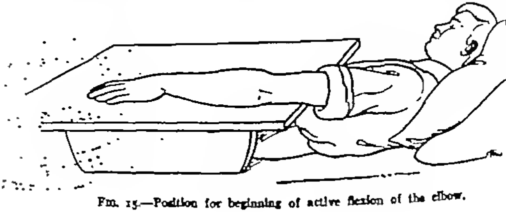

FIG. 15.—Position for beginning of active flexion of the elbow.

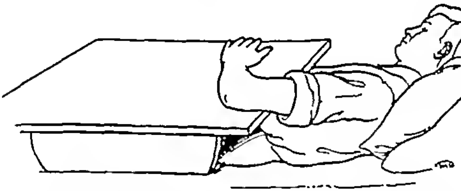

FIG. 16.—The starting position of active extension of the elbow. This also represents the position of the completion of the movement initiated in Figure 15.

in the blood content and flow. He finds that the capillary bed is "rather immobile and in a state resembling vasoconstriction" and responds inadequately to stimulation. The physiology of the treatment of acute muscular rheumatism, then, involves the vasomotor tone of the smaller arterioles, venules and capillaries. The restoration of vasomotor control has been previously described in this article, and the same methods are applicable here as elsewhere when their derangement is manifest.

Chronic myositis, or, as aptly described by Albee, "myofascitis," is an entirely different problem. Here two important pathologic processes are present besides the changes in the blood supply formerly described. The first of these is the tendency toward fibrosis, which results from the fibrositis of the muscle reticulum; the other is the

development of specific deposits in the muscle, often near its tendon attachment. These deposits can be felt on palpation of the patient's muscles. These nodes are capable of causing considerable pain on motion and often correspond to the definitely localized tender areas of chronic myositis. They correspond pathologically, in the main, to Aschoff's nodes, which are peculiar to rheumatic infections.

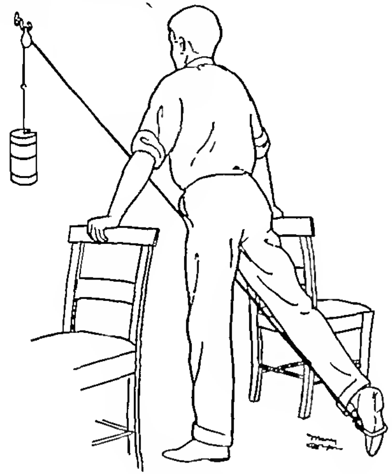

FIG. 17.—To show resistive exercise to the extensors of the hip.

One of the notable features of the symptomatology of chronic myositis is that, whereas the muscle is generally painful and tender on motion during acute myositis, when the acuity subsides, the patient will still complain of exquisite tenderness on motion, while, as a matter of fact, the pain on motion only exists if this movement causes compression of one of the nodes or areas of induration just described. The sufferer is apprehensive of all motion, and, although the acute process in the muscle has long since burned itself out, the feeling of constriction persists, due to fibrositis in the affected muscles, and he interprets this as pain. After the joints have once been forcibly

moved, he realizes that a large amount of motion of the joints and muscles is possible without the excruciating pain that he once experienced during the acute stage. This psychologic phenomenon is probably the basis of the many remarkable cures effected by unskilled bone setters and irregular practitioners of medicine who forcibly

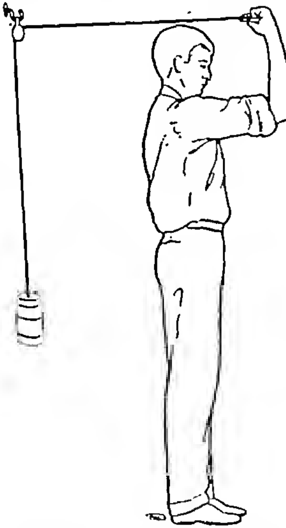

FIG. 18.—To illustrate resistive exercise for the brachialis anticus. (The biceps takes part in this action when forearm is in supination.)

manipulate the joints and muscles, liberating the muscle parenchyma from any fibrous deposits and restoring motion in a miraculously short time. In chronic myositis, when the possibility of gonorrheal or tuberculous infection of the nearby joints is eliminated, forcible manipulation under anesthesia in graded doses often aids greatly in expediting the return of function. Before each such manipulation, however, baking, massage and passive motions up to the threshold of pain

should be repeatedly performed. After the forcible treatment, baking, massage and passive motions must be resumed immediately to prevent the production of more disabling fibrous bands in the muscles.

There is no question but that baking and massage aid tremendously in the dissipation of the nodes just mentioned. Treatment of these nodes is an important part of the physical treatment of chronic myositis. Radcliffe recommends special massage, with deep thumbing movements about and under the deposits, always accompanied by kneading to stretch the adhesions and render these deposits more mobile. This is, of course, in addition to the general massage of the entire muscle involved. Marlin has applied galvanic current directly to the tender node, a needle attached to the negative pole being inserted and a current of five milliamperes being exhibited for three to six minutes. This, of course, must be accompanied by specific massage of the tender areas.

Some of the typical forms of chronic myositis can be mentioned. Very often, on examination, a few affected muscles can be picked out. Commonly, the latissimus dorsi, the serratus magnus, the pectorals, the long muscles of the back and the muscles of the calf and thigh present a definite increase in consistency to the palpating finger, and tenderness is elicited on palpation in the areas of greatest stiffness. An old trick used by osteopaths is to examine a man's back and tell him, before he has pointed it out to the examiner, exactly where the pain exists. This is easy to do under careful palpation with the examined muscles in a relaxed condition. The tender spot corresponds to an area of muscle spasm.

Lumbago.—Lumbago may be described as a typical form of chronic inflammation of muscles, although the fascia and fascial attachment and tendons of the back may or may not be also involved in the process. Early massage can frequently prevent full development of an attack. Generally, baking, followed by deep massage, will relieve the local condition. This treatment, however, is symptomatic. The original focus of infection or intoxication somewhere in the body, if such an etiologic factor exists, must, of course, be corrected. Careful diagnosis of the back case must be made to eliminate joint inflammations, and protective spasm to relieve faulty joint relationships must be ruled out before a case can be considered as a simple muscular lumbago. In treatment by massage, after suitable heat has been applied to relax the muscles, surface stroking over the long muscles of the back from the sacrum toward the dorsal region is followed after a few moments by deeper massage with the ball of the thumb, expressing blood from the muscles with each motion. It is generally necessary to treat the long muscles of the back well out from the region of spasm and pain, extending, for instance, if the complaint is pain in the upper lumbar muscles, low down over the sacrum and up over the muscles of the dorsal spine. Deep vibrations with electric vibrators aid in

establishing the circulation in the deeper muscles—for instance, the quadratus lumborum.

Stiff Neck or Rheumatic Torticollis.—This is quite similar in therapeutics to lumbago. After the application of heat, stroking should be applied over the entire course of the sternocleidomastoid and other muscles involved, followed by deeper kneading movements. Occasionally a chronic case is benefited by forcible manipulation, limited

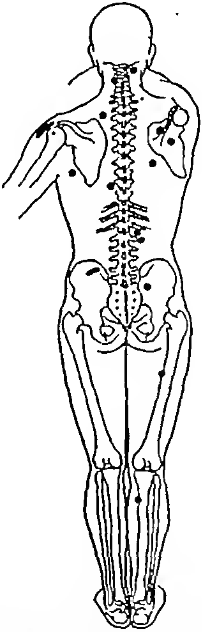

Fig. 19.—Diagram to show the commonest situations of sensitive deposits. (After James Mennell: in "Backache," Phila., P. Blakiston's Son and Co., Inc., 1931.)

in extent of motion, and preceded and followed by the usual physical treatment.

When the chronic muscle pathology is generalized and after the acuity has disappeared, gentle general exercises and massage are valuable. Shoulder circling increases the blood supply to all the upper muscles of the arm, and wrist and elbow exercises have a similar effect upon the lower muscles of this extremity. Trunk exercises are beneficial to restore circulation and relieve fibrosis in the chest, abdominal and back muscles. It is important to reëstablish full motion of all the muscles of the lower extremities before the various powerful fascial compartments have become shrunken from fibrosis and mechanically interfere with muscle movement.

Physical Treatment After Tendon Operations

Intelligent management of a case after a tendon operation has been performed depends upon a comprehensive knowledge of exactly what

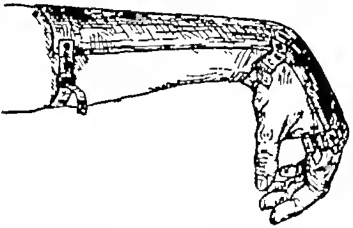

Fig. 10.—Method of splinting hand after a repair of the flexor tendons so as to allow early movement of the tendons. The muscles cannot pull strongly enough to break the tendon sutures as the splint holds them in relaxation. (From Lewis, Practice of Surgery, Hagerstown, Md., W. F. Prior Co., Inc., 1931.)

was done at the operation and the result which is expected from the operative interference. If repair or plastic operation of the tendon has been surgically correct, and adequate fixation sutures have been introduced to make the tendon *mechanically* sound, physical treatment can be begun immediately after the operation and even before the skin sutures have been removed; in fact, it is preferable to splinting a case for several weeks until the tendon heals and then expecting to overcome the fibrosis which occurs around the tendon after this condition is thoroughly established. If the physical therapist is in doubt as to the tensile strength of the tendon repair, it is necessary to allow a period of several weeks for the repair to become firm before any

movement of the nearby joints can be instituted. In the latter case, heat and massage can be applied to restore the normal circulation in the part from the beginning of the treatment, even before the tendon is firmly united. The operations upon tendons can be divided into tenotomy, tendon lengthening, fixation of a luxated tendon, transplantation, repair of lacerations and freeing adherent tendons.

Tenotomy.—This is done to correct a deformity and relieve the pull of an over-contracted or shortened muscle. If the operation is done subcutaneously, so that only a tiny skin puncture remains, massage and manipulation up to the point of pain, to reëstablish the proper joint position after the causal factor of tendon shortening has been removed, can be immediately instituted. The correction of joint deformity is the first objective in treatment. The second objective is strengthening of the weakened opposers, whose action has now been freed by cutting the spastic or contracted antagonists. The gradual restoration of joint function by manipulation of the joint through a range of motion up to the point of pain is generally preferable to forcible restoration. The patient must be trained to resume the function of the stretched muscles. Faradic current aids in retraining this lost muscle action. If an open operation has been done for tenotomy, it is important to prevent fibrosis in the operative scar by heat and massage, and, if there is any keloid tendency, by the application of a quartz light or minimum doses of x-ray. Tenotomies are often done about the feet to correct various talipes deformities. In this case, wrenching of the foot forcibly to correct the deformed joint position is done at the time of the operation, and, whenever swelling and edema result, these demand immediate physical treatment from the day of operation. The foot should be elevated and the baker applied several times a day, accompanied by light stroking massage toward the body, to encourage venous and lymphatic return. There is a curious fact connected with the distinction between *tenotomies* about the hand and of the foot. After tenotomy for a pes cavus or for destruction of the contracted tendons in a hammer toe, mobilization should begin as soon as possible, as all divided tendons about the foot tend to reunite unless every effort is made to prevent this. In tenotomies of the hand or wrist, however, union is quite slow, and there is no difficulty in preventing the tendon from growing together. Every active or passive motion employed in physical treatment should be one which tends to pull the separated ends farther apart.

Tendon Lengthening.—In tenotomy, with the exception of the Achilles tendon, which, under favorable circumstances, will regenerate, the tendon is sacrificed, whereas in tendon lengthening, the function of the revised muscle-tendon system can be preserved. A typical indication for the employment of tendon lengthening is in contraction of the muscles of the forearm, and an important consideration in

the physical management of these cases is that the operation be performed, not in the free part of the tendon, which has no blood supply through a mesotenon, but in the muscle at its junction with the tendon, as this latter wound will heal readily and allow the immediate institution of physical methods of treatment after the operation is performed. If the delicate tendons of the hand are lengthened in, or distal to, the wrist, no blood supply comes into the tendon through its mesentery, the mesotenon, and one must allow several weeks to elapse in order to insure a firm tendon union before manipulation of the nearby joints and active motion can be instituted. This is often a calamity, and, when treatment is finally begun, it is found that firm adhesions already bind the tendon in its sheath and only a part of the expected function can be reëstablished. Thus, it is not advisable to perform a tendon lengthening in a finger or where the tendon is covered by a sheath, but this should be done above and where the tendon passes through a paratenon, as in the forearm or above the ankle. Muscle stripping, as mentioned previously in connection with the operation of Baily in ischemic paralysis, is often more successful than operations on the tendon or at the junction of the muscle and tendon, as the region of the muscle where the stripping is done (at its origin) is much more thoroughly supplied with blood than is the tendon.

Tendon Fixation.—If proper muscular balance cannot be restored after the paralysis of certain muscles or muscle groups, by tendon transplantations, a fixation operation is of definite value. This operation consists of dividing the paralyzed muscle at its junction with the tendon and reuniting this divided tendon to the bone, which furnishes a check on the antagonistic muscles. Occasionally a strip of fascia is used for the same purpose in stabilizing a joint and preventing the antagonist of a paralyzed muscle from pulling a joint *into* a position of deformity. These tendons, anchored to the bone, are ordinarily passed through a hole bored through the osseous structure and require the ordinary time of three or four weeks for firm attachment to develop. Some strain on this new tendon preparation seems necessary to stimulate firm union. Such strain can be produced by very gently stretching a revised tendon at the time when massage and gradual stretching of the contracted antagonists are being performed. It is a curious fact that both bones and tendons will develop a [illegible] repair only if some function is required of them. This corresponds to Wolff's law of bone repair.

Muscle and Tendon Transplantation.—These [illegible] [illegible] essentially different. The reëstablishment of a [illegible] [illegible] stitution of a tendon attached to a healthy muscle [illegible] perform the function of another, depends on [illegible] technic in both the operation and the after-care. One is [illegible] as the other. By the physiologic method of [illegible]

by Mayer and Biesalski, the tendon to be transplanted is removed carefully from its bed after a long incision to expose its course. The mesotenon is carefully cut, and the tendon is slipped into the sheath of the tendon of the paralyzed muscle. This provides the tendon with a physiologic sheath and overcomes in large part the greatest obstacle to the resumption of function, adhesions. The first consideration of physical treatment is to prevent adhesions. If the insertion of the tendon is firmly anchored into, and not onto, bone, gentle passive motion can be started within the first two or three days, and active or assisted active motion in two weeks. Massage of the operative scar is begun as soon as the skin wound is healed, to prevent scar formation in the operative wound. Unless reëducation of voluntary motion is soon begun, the patient may never learn to use the revised muscle-tendon system. The gross movements must be reëducated before the finer ones. Coördination of the entire extremity can be reëstablished by rhythmic exercise of the larger joints first, then the smaller ones.

The transplantation of muscle origins has been recently made practical by the application of the method of transplanting a layer of bone, with the muscle origin, to some new bony prominence. An example of this procedure is Dickson's transplantation of the origin of the tensor fasciae femoris from the anterior to the posterior superior spine of the ilium, with a bone fragment, for paralysis of the gluteus medius. Telson has shifted the anterior portion of the gluteus maximus forward on the iliac crest for the same purpose. Bony union in these cases is expedited by minimum voluntary movements calling the transferred muscle into play.

Corrective operations for talipes unfortunately, for purposes of after-care of muscles and tendons, generally require a plaster cast for over-correction of the deformity or for retaining the fresh bone surfaces in apposition after an arthrodesis. Even if a cast is applied, it can generally be bivalved within the first few days and frequently removed for gentle massage, baking and the production of a minimum of passive movement in the new implanted tendons. The most satisfactory tendon transplantations in the foot are the peroneus longus to replace the tibialis anticus in equino valgus; the tibialis anticus, the fifth metatarsal for talipes varus; and the peronei with the flexor hallucis longus or tibialis posticus to substitute for the tendo achillis for talipes calcaneus (paralytic). In all three, a beginning retraining of muscle action can be accomplished by slight voluntary motion even while the foot is in the cast.

Tendon Repair.—The present tendency in careful plastic surgery is to omit the primary repair of severed tendons in the cases of lacerations of the extremities, unless the wound has been a clean incision, by a clean object, on a clean skin and not contaminated by subsequent soiled dressings in first aid. If such a clean wound is seen within a few hours after it is sustained, a primary suture may be attempted;

otherwise, an interval of several months after the original skin wound has healed is allowed before the tendons are repaired. The after-care is of tremendous importance. The extremity is put up in a position which completely relaxes the repaired muscle tendon. The length of time allowed before passive motion is instituted depends on the mechanical skill with which the tendons were united. Slight daily passive motion is enough to prevent tiny adhesions within the tendon sheaths. Such motion is begun by Koch and Kanavel from the first day, in cases where no infection is anticipated. The advent of infection destroys all the benefit of careful and atraumatic surgical repair. Bunnell recommends wearing a check-rein of adhesive plaster, holding the wrist and fingers in flexion for four weeks after repair of flexor tendons of the fingers, and later the application of galvanic current to contract the flexor tendon, sharply breaking fine adhesions. If adhesions constrict the tendons in spite of thorough treatment, a second operation for freeing them, followed by daily passive and active motion, is advised.

No tendon repair should be done by a surgeon who is not willing personally to supervise the after-care.

Tendon Luxations.—The commonest dislocations of tendons occur at the knee, where the patella may slip outward; at the malleoli, where the tibialis posticus or the peronei may luxate to a position under the skin; at the shoulder, by the long head of the biceps leaving the bicipital groove; or in the hand, where the extensor tendon of a finger may slip off the knuckle. In partial luxations, especially when due to mechanical trauma, splinting, followed by exercises to strengthen muscle groups stabilizing the tendon motion, may be successful. In complete luxations and those accompanying congenital deformities or due to poor muscle and tendon development, operative fixation of the tendon in a newly prepared vinculum tendinum of fascia or periosteum, followed by the usual physical treatment after the tendon operation, is more successful.

Vaginal and Mucous Bursae

It is important to emphasize that there is no essential difference in the types of affections which involve the two types of bursae. Churchman says that Albinus, in 1734, described sixteen pairs of sacs between tendons and bones and called them "bursae mucosae" to distinguish them from the sheaths about the tendons of the wrists and ankles, which Winslow had already identified and described as "bursae vaginae." Piersol has said that *bursae are sacs filled with liquid found in various places where friction occurs between different layers or structures. The tendons are often surrounded by* [illegible] and, according to Piersol's definition, *the joint cavity itself is a* [illegible] Our consideration is limited to the *vaginal or* [illegible]

by Mayer and Biesalski, the *tendon to be transplanted* is removed carefully from its bed after a long incision to expose its course. The mesotenon is carefully cut, and the tendon is *slipped* into the sheath of the tendon of the paralyzed muscle. This provides the tendon with a physiologic sheath and overcomes in large part the greatest obstacle to the resumption of function, adhesions. The first consideration of physical treatment is to prevent adhesions. If the insertion of the tendon is firmly anchored into, and not *onto*, bone, gentle passive motion can be started within the first two or three days, and active or assisted active motion in two weeks. Massage of the operative scar is begun as soon as the skin wound is healed, *to prevent* scar formation in the operative wound. Unless reëducation of voluntary motion is soon begun, the patient may never learn to use the revised muscle-tendon system. The gross movements must be reëducated before the finer ones. Coördination of the entire extremity can be reëstablished by rhythmic exercise of the larger joints first, then the smaller ones.

The transplantation of muscle origins has been recently made practical by the application of the method of transplanting a layer of bone, with the muscle origin, to some new bony prominence. An example of this procedure is Dickson's transplantation of the origin of the tensor fasciae femoris from the anterior to the posterior superior spine of the ilium, with a bone fragment, for paralysis of the gluteus medius. Telson has shifted the anterior portion of the gluteus maximus forward on the iliac crest for the same purpose. Bony union in these cases is expedited by minimum voluntary movements calling the transferred muscle into play.

Corrective operations for talipes unfortunately, for purposes of after-care of muscles and tendons, generally require a plaster cast for over-correction of the deformity or for retaining the fresh bone surfaces in apposition after an arthrodesis. Even if a cast is applied, it can generally be bivalved within the first few days and frequently removed for gentle massage, baking and the production of a minimum of passive movement in the new implanted tendons. The most satisfactory tendon transplantations in the foot are the peroneus longus to replace the tibialis anticus in equino valgus; the tibialis anticus, the fifth metatarsal for talipes varus; and the peronei with the flexor hallucis longus or tibialis posticus to substitute for the tendo achillis for talipes calcaneus (paralytic). In all three, a beginning retraining of muscle action can be accomplished by slight voluntary motion even while the foot is in the cast.

Tendon Repair.—The present tendency in careful plastic surgery is to omit the primary repair of severed tendons in the cases of lacerations of the extremities, unless the wound has been a clean incision, by a clean object, on a clean skin and not contaminated by subsequent soiled dressings in first aid. If such a clean wound is seen within a few hours after it is sustained, a primary suture may be attempted;

lining, as compared with many of the superficial bursae, is that the latter are easily destroyed by disease or scarifying agents and show more tendency to disappear completely after partial resection, inflammation or scarification and injury than the former. This termination is less important, so far as function is concerned, and is often the aim of treatment, whereas the mucosae vaginae must be intact if tendon function is to be conserved.

The Bursae Vaginae.—Several anatomic and physiologic considerations arise in connection with tendon-sheath pathology and treatment. Bunnell (Fig. 20) has shown that the protective covering and

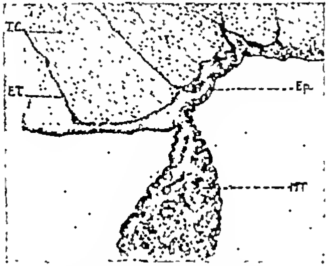

FIG. 22.—Mikroscopic cross section through the hilus of the extensor longus hallucis tendon (adult). Leitz obj. 3, oc. 1, tube 140. T. C. tendon cells; E. T. endotenon; Ep. epitenon; M. T. mesotenon

The mesotenon expands at its insertion into the tendon, forming a delicate tightly adherent connective-tissue enveloping layer—the epitenon. From the epitenon, connective-tissue septa extend into the tendon, separating it into larger and smaller bundles. These septa I have termed the endotenon (old terminology: peritenonium internum), as opposed to the esotenon, the connective tissue coating the surface of the tendon. Within the sheath the esotenon is represented by the epitenon and the mesotenon; above the sheath and at the two portals of the sheath by the paratenon. (From Lewis, Practice of Surgery, Hagerstown, Md., W. F. Prior Co., Inc., 1931.)

blood supply differ in the longer tendons, depending on whether the tendons exert a straight pull or must pass at an angle or around a corner to reach their attachment. In the former case, a tendon glides in the paratenon, a specialized fat between the tendon and the firm fascial compartments in the vicinity. Here the blood supply is ample, being supplied by branches from the muscle and helicine or tortuous vessels passing through the paratenon and long enough to follow the tendon movement. The loose, fatty tissue is attached to the tendon and glides with it. Fatty tissue is notably slow in developing fibrosis

ing tendons and the bursae mucosae. The former have the distinction, important in therapeutics, of having a true synovial lining, the stratum synoviale, while the latter are provided, according to Piersol, with a "more or less cellular lining," the degree of perfection of this synovial lining in the bursae mucosae being less complete in the subcutaneous than in some of the deeper bursae. According to Hamar, and also Braun, the synovial membrane of bursae is neither epithelium nor endothelium, but real connective tissue and, therefore, of mesodermal origin, and Jones has, consequently, suggested the name "mesothelium." The importance of the development of specifically differentiated and secreting lining membrane in the tendon sheath

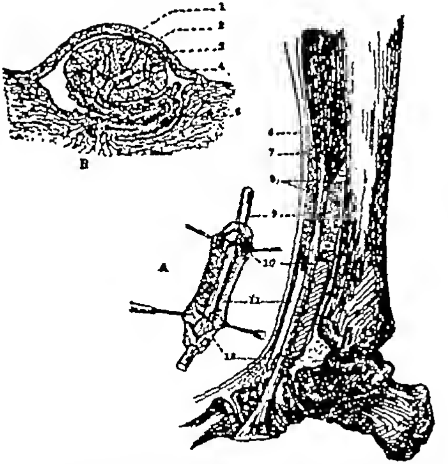

FIG. 11.—Anatomy and gliding mechanism of a tendon (tibialis anticus diagrammatic). Showing the proximal part of the tendon enclosed in paratenon fat, and just below it where the tendon turns a corner when in dorsiflexion showing the tendon passing through its sheath and obtaining its blood supply through its mesotenon.

(A). The sheath is looked into from the front, showing a plica duplicata at the upper end and a plica simplex at the lower.

(B). Cross section of tendon in sheath, showing the related blood-vessel-bearing mesotenon. 1-tendon, 2-endotenon, 3-epitenon, 4-sheath, 5-mesotenon with vessels, 6-skin, 7-fascia, 8-paratenon, 9-tendon, 10-plica duplicata, 11-sheath, 12-plica simplex. (From Lewis, Practice of Surgery, Hagerstown, Md., W. F. Prior Co., Inc., 1931.)

from using a scoop in filling bags and repeated supination in turning heavy ledger sheets. The reader is referred to Bunnell's excellent article on synovitis in "Lewis' Surgery." The pressure of puttees or heavy shoes on the peroneal and Achilles tendon results in exquisitely painful synovitis about the ankle.

As the tendon sheath becomes congested and roughened, fibrin is deposited on the synovial surface, and often a pathognomonic tendon crepitus can be felt or even heard on motion. Effusion, with a tender sausage-shaped swelling along the course of the tendon, may eventuate.

The symptoms may subside with a few days' rest and immobilization, but return when the offending motion is resumed. These constitute one of the most troublesome types of minor injury with which the industrial surgeon is confronted, as he is never able to make a definite prognosis, the most insignificant case sometimes being disabled for weeks or months. In the management of both the acute and chronic stages, absolute immobilization of the joints whose motion causes pain is indicated. For this affection in the thumb and extensors of the wrist and fingers, a cock-up splint serves admirably. If the flexors are affected, a dorsal splint, with the fingers and wrist completely flexed, is better. In all cases, the fingers must be completely immobilized. Massage, in our experience, is disastrous, and heat is best applied as diathermy for one to two hours daily. The danger of fibrous-adhesion development in the traumatic case is an important one. Some cases can return to work after all pain on motion has disappeared, wearing a leather wristlet or a liquid-plaster wrist and hand splint (Fig. 20).

Pyogenic Tenosynovitis.—The advent of tendon-sheath infection after trivial infected wounds of the fingers or hands requires immediate and wide surgical incision to drain thoroughly the sheath to the limits of involvement. Before the wound has healed, passive motion to prevent fibrous-tendon and tendon-sheath adhesions is imperative. This may seem radical but is urgently advised. Dry heat and passive motion with light stroking massage are indicated in the same case, as the motions of nearby joints must be conserved from the very beginning of treatment.

Gonorrheal Tenosynovitis.—In the course of an acute or chronic gonorrheal infection, a tenosynovitis may occur. Often this is described by the patient as following some minor contusion or strain. The industrial surgeon must be on the look-out for such an etiology in every supposedly traumatic case. Complement fixation and smears from the genitalia aid in deciding. The prognosis in these cases is much worse, as regards loss of function from adhesions and ankylosis, than almost any other type of synovitis. The course is prolonged. Vaccine therapy occasionally yields a startlingly rapid improvement. Active and passive motion and manipulation are contraindicated at all stages of treat-

and adhesions after injury or infection, hence the danger of constricting fibrosis in this portion or type of the tendon-muscle system is at a minimum. Operations for tendon repair or revision are best performed here. When gliding around a curve, the tendon moves in a smooth, lubricated tendon sheath lined with synovial membrane. This sheath is a closed sac, indented at the two ends to allow for motion of the tendon within it. The lubricating fluid changes with inflammation, and too much or too little fluid is the source of symptomatology. Pain on motion results from roughening of the synovial lining. Constriction of this sheath, which is, even under normal conditions, snug, interferes with the gliding and constricts the blood supply to the tendon. This blood supply to the tendon in its sheath generally reaches it through a loose mesentery, the mesotenon, capable of stretching in either direction to accommodate the limit of tendon motion (Fig. 21). If this is inflamed, the vessels which it carries are constricted, causing tendon ischemia or congestion with subsequent damage. The mesotenon may shorten from chronic inflammation, causing fibrosis and binding the tendon, restricting its motion mechanically. This delicate arrangement of a tendon in a snug sheath, with a lubricating fluid content and complicated blood supply, makes this a point of election for adhesive tenosynovitis and the constrictive affection first described by de Quervain as "stenosing tenovaginitis." This is a poor site for tendon operations. In some locations near tendon insertions, and in some individuals at all points in the sheath-enclosed tendon, it is entirely devoid of mesotenon. The tibialis posticus and flexors of the fingers are examples of this lack of adequate blood supply. What small blood supply these tendons receive must arrive from either end by tiny vessels in the tendons themselves. The slightest degree of inflammation or edema of the tendon obstructs this imperfect supply entirely. The tendon so supplied is in the worst possible situation for operation or repair, or for resistance to infection.

Tenosynovitis

The etiology of tendon-sheath inflammation may be traumatic; infectious, either pyogenic or specific (such specific types as gonorrheal, tuberculous or syphilitic); or may occur as a part of systemic disturbances like gout or "rheumatism." The objective in the treatment of all is the preservation of the function of the sheath, if possible.

Traumatic Tenosynovitis.—This may occur as a result of a single contusion or of repeated performance of an unfamiliar motion. The commonest type of the latter seen by the author occurs in the wrist around the tendons of the long abductor and the short extensors of the thumb. The exercise of the wrist in rowing, playing golf or tennis, or using a hammer may affect the flexors of the fingers and wrist. The commonest occupational synovitis in the author's experience results

Stenosing Fibrous Tenosynovitis of de Quervain.—In 1895 de Quervain, of Basle, Switzerland, described five cases of this malady, but no mention of it appears in American literature until Schneider, of Milwaukee, reported fifteen cases in 1928. In all these cases the sheaths of the abductor pollicis longus and the extensor pollicis brevis were affected, where these tendons pass under the superficial dorsal carpal ligament, although from clinical observation we know that a similar process probably develops about the ankle, particularly around the peroneal tendons after os calcis fracture, and about the extensors at the wrist. Some of the cases of de Quervain and Schneider resulted from monotonous use of the thumb, occasionally following a single trauma to the dorsum of the wrist, while some appeared to have a "rheumatic" background. Roentgenograms revealed a calcareous deposit on the radius at the site of the fibrocartilage disk, probably in the diseased tendon sheath where it is closely adherent to the bone. De Quervain found a fibrosis in the middle layers of the tendon sheaths. Nussbaum, in operating on these, described five layers in the sheaths, with the middle layers composed of firm connective tissue arranged at right angles to each other, that is, one longitudinal and the other transverse. These two layers presented marked fibrosis, constricting the sheath which was too narrow for the tendon to pass.

These patients complain of severe pain on extension and abduction of the thumb, being often entirely unable to accomplish these motions. Even gripping and ulnar motion, or extension of the wrist may produce pain. A thickening may be palpated on the dorsum of the lower end of the radius, but there is no redness or crepitation on motion. Despite rest of the extremity and the application of electric heat, the pain becomes increasingly severe. Schneider cured seven cases in ten by the application of a plaster splint, including the thumb and forearm, but several were relieved only by surgical intervention. In some, as de Quervain suggested, he split the involved tendon sheaths, including the dorsal carpal ligament, and applied a cast. Later, heat, light, massage and active motion were given, and, in the operative cases, all recovered completely.

Decompression operations based on this principle are advised in all cases of chronic synovitis in which the subjective symptoms are not relieved in a reasonable time—four to six weeks—by complete immobilization and baking. Many months of loss from remunerative employment can be saved the patient by timely surgical intervention in resistant tenosynovitis.

Bursitis

For purposes of treatment, *bursae mucosae* can be considered in two classes: (1) Superficial and subcutaneous bursae, which vary considerably in size, number and position and are not necessary to the function of moving structures. All remedial treatment can be

ment, until months after all subjective symptoms have disappeared. Adhesions cannot be prevented in this affection. Ankylosis and fibrosis must be expected. The probable loss of function should be explained to the patient early in the course of treatment.

Tuberculous Tenosynovitis.—This commonly affects the sheaths of the extensor or flexor tendons at the wrist or, less commonly, those about the foot and ankle. Early in the course, it is mistaken for a mild tenosynovitis resulting from a trivial injury, but the progression of swelling, due to either serous effusion or perisynovial hyperplasia, without much tenderness, redness or pain, marks the case as the result of some specific granuloma. There may or may not be a demonstrable focus of tuberculous infection elsewhere. If a nearby joint is involved, the diagnosis is quite simple. The distinction from a syphilitic affection cannot easily be made except by the serologic tests on the blood or cerebrospinal fluid. If syphilis is diagnosed, the local treatment of the synovitis is greatly aided by general specific treatment. Tuberculous synovitis can be approached in two ways: by the conservative treatment, such as used for joint tuberculosis, comprising complete fixation of the part aided by both local and general heliotherapy, and by hyperalimentation. The general care of the tuberculous patient is as important as rest of the focus of infection. If, after several months, the local disease is progressing—that is, swelling increases and sinuses appear as the process is extending along the muscle-tendon system—or there is evidence of necrosis of tendon, complete excision of the tendon sheath and pathologic tissue in the vicinity, including the necrotic tendon, must be performed. Kanavel seems inclined toward this radical treatment early in the course of the disease as leaving a better condition in which to begin reconstructive and reëducative treatment of the remaining intact structures of the part. Bunnell suggests early incision into the tendon sheath and the introduction of 5 per cent iodoform in glycerin, followed by prolonged immobilization on a splint. However, the general rule can be made that if a tuberculous focus in the tendon sheath is not improving in appearance after a few weeks of splinting, one sort or other of surgery is indicated.

Rheumatic and Gouty Inflammation of the Tendon Sheath.—This is diagnosed by the occurrence of foci elsewhere. In the rheumatic affection, the tender swelling may appear suddenly. A history of various joint, muscular or bursal affections elsewhere makes a diagnosis. The acute stages demand splinting and gentle baking. After the local focus of infection or allergic reaction has subsided, heating followed by passive motion and retraining of atrophied muscles aids in preventing deformity and loss of function. The general physical treatment of rheumatism is of as much importance as local measures.

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directed toward the obliteration, destruction and removal of these structures, since they are not necessary to the function of the part. Furthermore, constant or repeated pressure easily results in the formation of a new adventitious bursa wherever such a structure is needed. Inflamed bursae of this type can be aspirated and the lining scarified or injected with escharotics. After aspiration, large doses of diathermy, followed by compression bandaging, may result in their obliteration. If purulent infection develops, wide incision and packing or complete surgical removal results in a cure.

(2) The deeper bursae are of far greater importance in function. They may be classified as: (a) subfascial, aiding the motion of fascial planes upon each other; (b) submuscular, which are between two muscles, between a muscle and some skeletal part or between a muscle and a tendon; (c) subtendinous bursae, which are between tendon and bone, between tendon and ligament or between two tendons; (d) periarticular bursae, like the bursae subscapularis and bursae subcruralis, which often connect with a contiguous joint. These deeper bursae are important as being the location of much obscure pathology and mistaken diagnosis. The surgical approach is often difficult or exposes important structures, so that surgical removal is not always feasible without a destructive operation. The tendency to communicate with nearby joints accounts for the danger of the extension of an infection from bursa to joint.

Being quite like the tendon sheaths and joint cavities in development and anatomy, the bursae mucosae present the same pathologic reactions to trauma, infection and irritation as do the former structures. In chronic bursitis, resulting from trivial trauma or repeated unusual motion, the question of a rheumatic element in the inflammation always enters the mind of the examiner.

Because of the complicated arrangement and contiguity of important structures, all types of bursal pathology, except purulent infection, should be given the benefit of thorough and prolonged physical treatment before operative intervention is contemplated. For an intelligent approach to the treatment by physical means, the physician must visualize the probable pathology of the bursa and surrounding structures at different stages of inflammation. Deering has admirably classified these stages somewhat as follows:

1. Acute reactions with effusion or fibrin deposition beginning.
2. Fibrous adhesions forming and contracting, with associated fascial fibrosis and sometimes periarticular fibrosis in a contiguous joint.
3. Muscular atrophy.
4. Calcium and fat deposition in the bursa or obliterative fibrosis.

Sometimes the inflammation begins insidiously, with no acuity, stiffness of nearby joints and pain on motion being the first complaint. The early local treatment consists of heat, particularly diathermy, and absolute rest of the part in a position relaxing pressure upon the

affected bursa. Gentle massage up to the pain threshold maintains muscle nutrition and relaxes spasm. This, if unrelieved, would result in muscle atrophy and fibrosis. Elevation is indicated in cases of hyperacuity or pathology suggesting pyogenic infection. Repeated aspiration is indicated in the first stage, as long as the bursa is markedly distended with fluid. In the second stage, fibrous adhesions in the bursa and nearby tendon sheaths or between muscles must be prevented, even at the expense of some pain to the patient, by means of gentle manipulations and active stretching exercises to maintain joint, tendon and muscle movement. Heat is continued.

Often the case is seen first during the third stage, when the acuity has subsided but much associated pathology of muscle atrophy and fibrositis is already established. Besides the physical treatment already mentioned, forcible manipulation under gas is necessary, in graded operations, however, at each treatment only a few degrees of one movement being attempted and followed by massage and baking. For instance, in the neglected third stage, subdeltoid bursitis, only a few degrees of abduction of the stiffened and atrophied shoulder muscles are attempted the first time. Later, complete abduction is accomplished and, still later, external rotation and, lastly, internal rotation. Faradic stimulation of functionless muscles with a Smart-Bristow coil initiates muscle retraining. Assisted exercises follow the institution of voluntary muscle action.

In the last stage, when calcium salt or amorphous fat can be seen filling the bursa, diathermy has an almost specific action in hastening its resorption.

Special Forms of Bursitis

The chronic cases presenting no positive roentgenologic findings are often mistaken for traumatic periostitis, neuritis, articular synovitis, a primary affection of nearby tendons or their sheaths, or myositis. A definite diagnosis is imperative to enable one to make a decision between operative and physical treatment.

Bursae About the Shoulder.—All types of inflammation in the structures about the shoulder joint are characterized by pain on motion of the joint, limitation of motion and a tendency to hold the arm adducted against the side. It is difficult to make an accurate differential diagnosis of the pathology and the etiologic factors involved in this symptom picture. The subdeltoid or subacromial bursa is the most frequent of the structures outside the joint cavity proper to present lesions of traumatic or inflammatory etiology. A fall on the outstretched arm brings the greater tuberosity smartly against the acromion process. Continual exertion with the arm hyperextended irritates structures covering these bony processes, in a less violent manner. If the patient has a tendency to synovial irritation from some chronic toxemic or allergic reaction affecting joint and synovial

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tion of the supraspinatus tendon. In lesions of this tendon, internal rotation and abduction are more painful than external rotation and abduction, which latter are more painful in the subdeltoid affection. An x-ray taken with the arm rotated outward, the tube focused from a position close to the base of the neck and directed downward and posteriorly, is likely to show the supraspinatus pathology, while an ordinary anteroposterior flat plate visualizes the subdeltoid bursa clearly. The distinction in subdeltoid and supraspinatus pathology from the standpoint of treatment is an important one, since chronic inflammation in the former yields much more readily and uniformly to diathermy and the abduction splint than the latter, which gives a much more hopeful prognosis of function return after early operation for removal of the pathology in the tendon. Harbin finds the area of degeneration and calcium deposition often entirely limited to the tendon at operation, without any associated changes in the subdeltoid bursa. The tissues within and beneath the deltoid muscle share with those about the elbow joint in a characteristic tendency toward calcium deposition after injury or irritation. Schojenioff found that calcium may be deposited in the deltoid muscle fibers within 36 hours after suture of a laceration of this muscle. Calcium deposition proceeds *pari passu* with a tendency to fibrosis, making any shoulder injury particularly likely to result in early stiffness and limitation of motion.

Acromial bursitis is quite superficial, and the inflamed bursa can be palpated near the surface at the top of the acromion.

Tenosynovitis of the long head of the biceps presents a tenderness far anterior, under the deltoid and along the bicipital groove. External rotation and extension of the shoulder are painful, as is bicipital action. Local crepitus may be present.

Bursitis of the coraco-acromial, subscapular and infraspinatus bursae is rare, and the tenderness is localized and not adjacent to the subdeltoid tender points. The first may be located under the coracoid process in front, or farther anterior, beneath the combined tendon of the coracobrachialis muscle and the short head of the biceps. The subscapular bursa lies between its muscle and the joint capsule with which it typically communicates, and inflammation rarely involves this without, or is diagnosed separately from, disease of the joint proper.

Periostitis of the humerus at the deltoid insertion may be traumatic from forcible deltoid action, or associated with myofascitis here. Abduction is painful, but no other signs of subdeltoid bursitis are present, and x-ray may show a local roughening or exostosis of the periosteum. These yield slowly to diathermy, but shoulder-joint motions can easily be preserved.

Brachial neuritis, or radiculitis with or without roentgenologic evidence of cervical arthritis, is more tender at the nerve exits from the cervical spine and tends to produce pain radiating along the upper border of the trapezius and definitely down nerve trunks of the arm.

surfaces, less friction is necessary to produce serous or plastic reactions of bursal surfaces.

Codman investigated the pathology of subdeltoid bursa reactions 23 years ago and described this bursa as follows: "Its base is formed by the tuberosity of the humerus and the tendons of its rotators, which are inserted into the tuberosity. Its roof is formed by the periosteum beneath the clavicle, the coraco-acromial ligament and the acromion, and by the upper part of the fibers of the deltoid muscle. Its limits beneath the deltoid muscle vary considerably, but the outline is likely to be trilobar, like a clover leaf, and to extend below the edge of the point. On the whole, it is circular in outline, concavo-convex in shape, and about the size of the palm of the hand." The sensory nerves arising from the shoulder joint and from this large subdeltoid bursa, which may be spoken of as an accessory shoulder joint, go to the same cord level which supplies motor impulses to the muscles in close proximity to the shoulder joint, and sensory irritation is reflected to these muscles as protective spasm, fixing the shoulder in adduction and slight internal rotation. This position is identical with that of decerebrate rigidity and allows the powerful adductors and internal rotators to stretch the weaker external rotator and abductor groups. The establishment of function of the weaker group about any joint is more difficult than rehabilitation of their stronger antagonists, particularly when the stronger group, as here, are the "gravity muscles" with "plastic tone." On physical examination, the greatest tenderness is found either over the middle of the deltoid or over its insertion, or distributed in both of these points. Pain on abduction may begin with the first few degrees of motion and be localized on the outer aspect of the arm at the deltoid insertion, or suddenly appear at about right-angle abduction, localized just below the acromion. No pain or tenderness should be expected in the uncomplicated subdeltoid lesion over the anterior border of the deltoid or about the bicipital groove of the humerus. In examining shoulder motion, it is an important item of technic for the examiner to seize the scapula firmly and prevent its rotating motion to replace the shoulder joint motion in the stiffened or painful shoulder. Codman's test of having the patient flex the spine forward and let the arms hang down, then arise, bringing the arms up to the horizontal with the body, is important. When this maneuver is performed, a sharp pain is generally experienced in the shoulder when the erect position is resumed and the humeral head is brought up against the acromion.

In 1906, Dawbarn described a sign rather characteristic of proliferative changes or calcium deposition in the supraspinatus tendon, in studying subdeltoid bursitis, but Stevens, in 1909, first recognized a distinction between the former condition and subdeltoid bursitis proper. The sign mentioned consists of a point of tenderness just above the tuberosity of the humerus, which disappears under the acromion on extreme abduction of the arm. This is rather constant in calcifica-

tion of the supraspinatus tendon. In lesions of this tendon, internal rotation and abduction are more painful than external rotation and abduction, which latter are more painful in the subdeltoid affection. An x-ray taken with the arm rotated outward, the tube focused from a position close to the base of the neck and directed downward and posteriorly, is likely to show the supraspinatus pathology, while an ordinary anteroposterior flat plate visualizes the subdeltoid bursa clearly. The distinction in subdeltoid and supraspinatus pathology from the standpoint of treatment is an important one, since chronic inflammation in the former yields much more readily and uniformly to diathermy and the abduction splint than the latter, which gives a much more hopeful prognosis of function return after early operation for removal of the pathology in the tendon. Harbin finds the area of degeneration and calcium deposition often entirely limited to the tendon at operation, without any associated changes in the subdeltoid bursa. The tissues within and beneath the deltoid muscle share with those about the elbow joint in a characteristic tendency toward calcium deposition after injury or irritation. Schujenioff found that calcium may be deposited in the deltoid muscle fibers within 36 hours after suture of a laceration of this muscle. Calcium deposition proceeds *pari passu* with a tendency to fibrosis, making any shoulder injury particularly likely to result in early stiffness and limitation of motion.

Acromial bursitis is quite superficial, and the inflamed bursa can be palpated near the surface at the top of the acromion.

Tenosynovitis of the long head of the biceps presents a tenderness far anterior, under the deltoid and along the bicipital groove. External rotation and extension of the shoulder are painful, as is bicipital action. Local crepitus may be present.

Bursitis of the coraco-acromial, subscapular and infraspinatus bursae is rare, and the tenderness is localized and not adjacent to the subdeltoid tender points. The first may be located under the coracoid process in front, or farther anterior, beneath the combined tendon of the coracobrachialis muscle and the short head of the biceps. The subscapular bursa lies between its muscle and the joint capsule with which it typically communicates, and inflammation rarely involves this without, or is diagnosed separately from, disease of the joint proper.

Periostitis of the humerus at the deltoid insertion may be traumatic from forcible deltoid action, or associated with myofascitis here. Abduction is painful, but no other signs of subdeltoid bursitis are present, and x-ray may show a local roughening or exostosis of the periosteum. These yield slowly to diathermy, but shoulder-joint motions can easily be preserved.

Brachial neuritis, or radiculitis with or without roentgenologic evidence of cervical arthritis, is more tender at the nerve exits from the cervical spine and tends to produce pain radiating along the upper border of the trapezius and definitely down nerve trunks of the arm.

The median or circumflex trunk may be tender to palpation in the lower third of the arm.

The principles of treatment correspond to the general rules for the management of bursitis anywhere. Immobilization on an abduction splint, with complete external rotation, often cannot be accomplished until gradual stretching of the contracted adductors and internal rotators has restored motion to the shoulder. Confinement to bed in the supine position, with the arm in a sling tied to the head of the bed, aids in gradual abduction. Most disabilities of the shoulder joint are best immobilized in this position. If calcium deposits are not resorbed from the bursa after a few weeks' administration, open operation is indicated for the removal of the contents and as much of the thickened bursal wall and underlying periosteum as can be exposed in the field. Physical treatment must continue thereafter.

Of the deeper bursae about the elbow, the ones under the tendinous insertion of the triceps or within the fibers of this insertion are difficult to approach surgically, without some damage to an important muscle tendon. Not enough fluid collects in these bursae to be successfully aspirated. A surrounding fibrosis is the most troublesome feature. Radiohumeral bursitis, "epiphysitis" or tennis elbow, characterized by severe pain over the outer side of the elbow and a point of tenderness over the external epicondyle, is generally considered as due to inflammation of a small bursa lying between the conjoined tendon and the radiohumeral joint. These have been operated on successfully by Osgood, but can, in our experience, be treated successfully by complete immobilization of the elbow in semiflexion and with the forearm in the midposition between pronation and supination. Diathermy is applied daily up to the "toleration" dose. This treatment should relieve all symptoms in three to six weeks. Active motion of the arm can then be resumed, but violent exercise or the performance of the peculiar type of movement originally responsible for the irritation should not be repeated. Recurrences are common, and, if a chronic painful stage develops, operative interference should be undertaken.

Several deep bursae about the hip require physical treatment. Bursitis about the great trochanter is easily mistaken for osteomyelitis, tuberculosis of the hip or epiphysitis. Careful diagnosis is essential. Splinting, rest in bed and diathermy are successful if treatment is continued for a long enough period and no suppurative process is present. The iliopectineal and iliopsoas bursae vary in size and position. Inflammatory processes here can be mistaken for psoas abscess, femoral hernia or coxitis. Aspiration may aid in diagnosis and treatment. Physical therapy should be given a prolonged trial before operative intervention. Pathology in the ischial bursa is easily approached surgically and should be dissected out.

Subcutaneous bursae about the bony points of the feet and ankle vary considerably in distribution. Adventitious bursae readily develop from constant pressure of shoes upon bony swelling and deformities.

Typical of this is the bursa commonly appearing and frequently the seat of pain and swelling over a bunion. Surgical dissection may leave tender scars when care is not exercised in choosing a skin flap which will not leave a suture line passing over a bony prominence. The deeper bursae, when inflamed, are generally not palpable but produce exquisitely tender areas in characteristic locations. Sharp bony spurs may grow from the periosteum beneath, or protruding into, contiguous ligaments or fascial planes. These osteophytes must be thoroughly excised with the underlying periosteum before physical treatment of the inflamed bursa can be undertaken. There are four distinct sets about the os calcis capable of producing disabling symptoms:

1. At the attachment of the adductor hallucis brevis, the flexor digitorum brevis muscles and the plantar fascia, just beneath the sustentaculum tali is the anterior calcaneal bursa. It lies beneath the short flexors of the foot and anterior to the posterior tubercle of the astragalus in a region of difficult surgical approach.
2. More superficial than this, on the inferior surface of the tuberosity of the os calcis and covering this bony prominence, is the posterior calcaneal bursa.
3. Anterior to the Achilles tendon, on the neck of the os calcis, lies the retrocalcaneal bursa.
4. Anterior and internal to this bursa and in close relation to the tendons of the posterior tibial and flexor longus digitorum muscles are other bursae of irregular size and position.

In chronic stages of inflammation, roentgenologic evidence of thickening or calcium, or fatty contents may be seen. Baking and the maintenance of the part in absolute immobilization will alleviate the symptoms of the bursitis.

Pitfalls in the Physical Treatment of the Muscle-Tendon System

1. The most important pitfall applying to muscle, as to all physical, treatment is the danger of treatment of the local pathology without a careful physical examination and history to rule out the etiologic factor of a general disease or distantly located cause for the local pathology.
2. Tumors and swelling of tendons and muscles should be approached from a standpoint of physical treatment only after a positive diagnosis is made. Benign tumors of the former are surgical. Little can be expected from physical means before the mechanical interference of the swelling with function is removed. No muscle tumor can be trusted not to become malignant. Physical treatment may aid in its dissemination or metastasis.
3. Increased swelling, tenderness, superficial congestion, pulsation or telangiectasis developing while a muscle is under treatment carries

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the suspicion of malignancy. X-ray should check this possibility from time to time.

4. Myositis ossificans represents the culmination of a constitutional tendency. The connective tissue of injured or inflamed muscles, tendons and fascia progressively changes to bone. The brachialis anticus and other muscles about the elbow, which are commonly affected, develop increasing stiffness during a course of physical treatment. Rest should be immediately substituted for massage and motion, which increases the calcium deposition. Roentgenograms indicate the stage when bone ceases to be deposited and the resulting bone can be surgically removed.

5. Trichinosis should be suspected when myositis becomes more acute during treatment and a biopsy on the affected muscle reveals the encapsulated larvae. Physical treatment should be replaced by anthelmintic management until the acuity passes in the course of weeks.

6. Syphilis and tuberculosis of muscle tendon and tendon sheath must constantly be borne in mind, watched for and appropriately managed by general antisyphilitic treatment or the adoption of a régime for the cure of tuberculosis.

7. The *bête noire* of tendon treatment is fibrosis. Early slight motion is infinitely more successful than delayed and more robust treatment.

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CHAPTER SEVEN

PERIPHERAL NERVE LESIONS

Lewis J. Pollock, M.D.

Injury or disease of a peripheral nerve produces among other things a loss of motion which, if complete, is called paralysis, and if incomplete, paresis. Not all of the loss of motion seen in peripheral nerve lesions is the result of the defective conduction of such a nerve. Some of it may be the result of local shock, pain, swelling of tissues, fractures, dislocations, adhesions, ankylosis, contractures of opposing uninjured muscles, spasm, sclerosed fibrous tissue, as in ischemic paralysis, tendon and muscle section or loss, and hysteria.

Examination

Many of the nerves when injured produce a paralysis of certain muscles, which leads to a characteristic deformity. Of such, mention may be made of the wrist drop of radial nerve palsy, often associated with "tumor of the wrist," due to distention of the ligaments, producing a protrusion of the proximal metacarpal bone; the position of a foot drop in peroneal nerve palsy; the characteristic clawing in ulnar nerve palsy; the ape hand in ulnar and median nerve palsy; the winged scapula in long thoracic nerve palsy, etc.

Limitation of movement of joints frequently results and the range of motility may be determined by a goniometer and measured in degrees of a circle, or by tracings obtained from moulds with a flexible lead tape (Fig. 1), first obtaining a tracing of the position in one direction (flexion) and then in the opposite direction (extension).

When examining for a range of passive movement, attention must be given to the position of the extremity and its parts; for example, flexion of the fingers is more limited with the hand flexed at the wrist than extended. Similarly, in combined ulnar or median nerve lesions, extension of the fingers will be more limited when the hand is extended at the wrist. Dorsal flexion of the foot will be limited with the legs extended in peroneal nerve lesions.

Movements of Segments About Joints.—It is impossible to examine each muscle separately for evidence of paralysis, and we are compelled to infer its functional capacity by the active movements of segments about joints. In such an examination the part of the extrem-

sively moved, active motion may continue the movement, and if a position of the extremity is passively imposed, the paretic muscle may hold the extremity in this position.

The amount of weakness may be determined by comparing the strength of movement against gravity or interposed resistance, either with a dynamometer, or with the unparalyzed side or the examiner's resistance. A simple dynamometric method may be employed by interposing a spring scales between the segment to be examined and the examiner's hand. Each movement about the joint may be so examined and recorded. Pronation and circumduction may be investigated by fastening a small flat piece of wood in the patient's hand and inserting the hook of the scale in a hole drilled through the wood (Fig. 2).

Many factors other than paralysis produce loss of function and require treatment. Changes in the joints are a very common complication of peripheral nerve lesions. They may result from fractures into

FIG. 2—Spring scale dynamometer.

the joint, dislocations, suppurations of the joint and nearby parts, immobilization, ischemic contractures, etc.

Occasionally an early arthritic change, consisting of painful swelling, is seen which may persist for weeks and be followed by partial ankylosis. At other times, gradual retraction of muscle tendons and hardening of the capsule of a joint occur. Such changes are more often encountered in partial and painful nerve lesions, such as are seen in injury of the median and tibial nerves. Interphalangeal joint changes are particularly disabling and care must be exercised to prevent them, if possible.

Shortening and contractures of opposing unparalyzed muscles occasionally occur, at times because of neglect to splint the extremity, at times because of prolonged overcorrection, and at times despite good treatment.

ity proximal to the joint being examined must be immobilized. For example, in testing for extension at the wrist, the forearm should be immobilized. Care must be exercised in properly evaluating that loss of function which results from the deformity's producing defective action of opposing muscles, such as the defective flexion of the fingers resulting from the wrist drop of radial nerve palsy.

The extremity must be placed in such a position that the force of gravity will be nullified. An enfeebled muscle may be able to move part of an extremity when supported, but not when opposed by gravity; as in circumflex nerve injury, the deltoid muscle may be strong enough

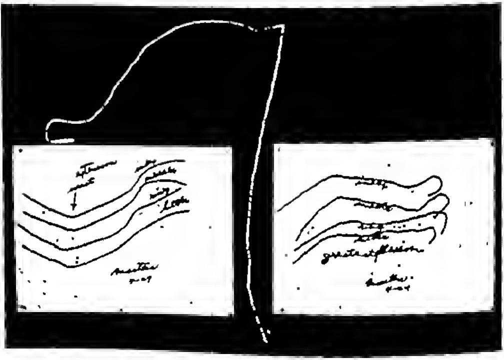


FIG. 1—Lead tape and tracings.

to produce abduction of the arm if the arm is held supported on a powdered board, but too feeble to produce movement with the arm dependent.

At times the movement produced by gravity might be misinterpreted as active motion; for example, extension of the forearm after flexion has been produced with the patient standing erect is, of course, only the result of gravity controlled by the unparalyzed biceps.

At times no motion of the extremity may be produced but a contraction may be felt in the paretic muscle by palpation, or relaxation may be felt upon contraction of the opposing muscles; as in paralysis of the deltoid muscle, strongly resisted adduction of the arm is accompanied by relaxation of the deltoid. At times, if a part of an extremity is pas-

Special attention should be directed to the misinterpretation of certain movements which are possible, or become so, after certain nerves have been injured. Unless one is familiar with these supplementary or trick movements, a completely paralyzed muscle may be thought to have recovered function. Such movements result from the anastomotic supply of muscles from adjacent nerves, from the action of muscles other than those which are primary movers. For example, flexion of the wrist may be produced by contraction of the extensor ossis metacarpi pollicis, by movements resulting from mechanical factors when tendons act over several joints. Extension at the wrist may be produced by complete flexion of the fingers in radial nerve palsy (Fig. 3); by the elastic recoil of movements in the opposite direction, as the extension of the distal phalanx of the thumb following flexion; and by gravity.

Response to Electrical Stimulation.—The response of muscles to electrical stimulation often gives indication of the state of recovery, or function. Normal muscles and nerves react to electrical stimulation in a characteristic manner. The make or break shock of a galvanic current produces a rapid, lightning-like twitch of the stimulated muscle, and faradization produces a tetanus. The muscles react to the stimulation of the negative and positive poles in a constant manner and a formula of polar contraction may be expressed as follows: (K. C. C.) Kathodal closing contraction is greater than (A. C. C.). Anodal closing contraction is greater than (A. O. C.). Anodal opening contraction is greater than (K. O. C.) (K. C. C. > A. C. C. > A. O. C. > K. O. C.)

Ten to fourteen days following injury to a peripheral nerve certain changes occur in the reaction to electrical stimulation which, grouped together, constitute the reaction of degeneration (D. R.). These changes may be described as quantitative, qualitative, modal and polar. The excitability of the nerve to faradic and galvanic stimulation is lost. The muscle loses its irritability to the faradic current (qualitative). In the early stages, for about two weeks, the muscle is hyperexcitable to the galvanic current, but later becomes less and less excitable (quantitative). The character of the response changes from a rapid twitch to a slow vermicular contraction (modal). The polar formula is reversed, the A. C. C. being greater than the K. C. C. The most valuable and most constant of these signs is the slow contraction of the muscle.

Because of the diffusion into unparalyzed muscles when a unipolar method of stimulation is used, the bipolar method, wherein both poles are placed upon the muscle being examined, is preferable. The extremity to be examined must be relaxed and the segments about joints must be so supported that the muscles are not required to act against the power of gravity. Supplementary movements may be produced by electrical stimulation and one must be alert to recognize these.

Atrophy is a common accompaniment of paralysis of a muscle resulting from peripheral nerve lesions. Study of the amount of tissue loss following such lesions shows that the cases carefully treated by physical therapy have far less loss of volume of the tissues of an extremity than do the untreated cases.

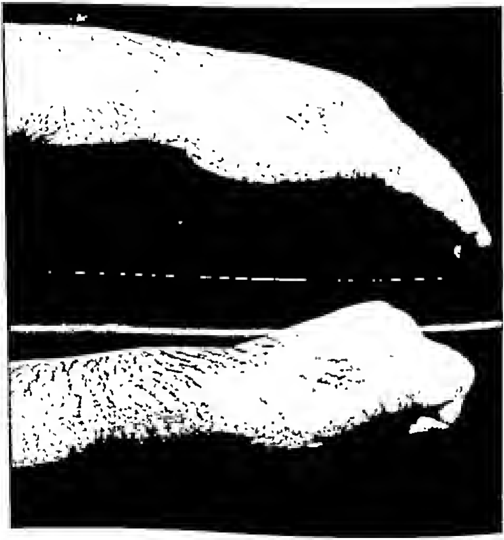


FIG. 3—Extension of wrist by supplementary motility.

Sclerosing fibrous tissue, as in ischemic paralysis or associated with vascular lesions, produces long-lasting loss of function which is very resistant to treatment. The loss of function does not follow the motor distribution of any peripheral nerves, and the responses to electrical stimulation are not characteristic of reaction of degeneration, but there is a diminution of response to both faradic and galvanic current.

Where a primary or secondary suture is indicated immediately, physiotherapeutic treatment must assist the operative procedure. When it is felt advisable to defer the operative procedure, physical therapy must be initiated promptly to the end that when the nerve regenerates it will activate a mechanism capable of adequate movement.

The above indications are met by treatment with splinting to prevent overstretching of paralyzed or weak muscles; massage to improve the nutrition of the parts, to prevent adhesions of scars and fibrosis and to conserve the bulk of the muscle; passive movements to prevent deformity from shortening, interphalangeal fibrosis, ankylosis of joints; active exercise to conserve the unparalyzed muscles, to stimulate circulation, to educate synergistic muscles to assume the function of paralyzed muscles; electrotherapy to conserve the vitality, prevent complete atonia, and increase the contractility of paralyzed muscles, and hydrotherapy and thermotherapy to assist in nutritional conservation and to facilitate other methods of treatment.

In cases treated some time after injury, splinting and the other procedures are indicated to correct deformities, as well as to restore function. Here passive movements must include stretching of shortened muscles and tendons, and mechanical devices constructed to assist in this function. Corrective exercises and occupational therapy play a large part in the correction of such deformities.

Splints to Prevent Deformity.—The purpose of the splint is to put the paralyzed muscle at rest and prevent overstretching of the muscle, and to resist spasm of the opposing muscle. Each splint must be devised for a particular patient because the mechanism of the joints over which the paralyzed muscles act differs in each individual. The splint should be light, simple, easily applied and removed, inexpensive, and as inconspicuous as possible. The material from which splints are constructed differs in the hands of various workers. In general, the splints used by the British and French during the World War were far more complicated than those used in America. Aluminum is a satisfactory metal to work with. It is light, and when necessary, small adjustments may easily be made to the shape and other characters of the splint, as indicated.

Following a primary or secondary suture, particularly the latter, where it is often necessary to place the extremity in an abnormal position to permit of approximation of the severed ends of the nerves, a plaster of paris cast or splint must be applied for a period of two weeks. Following this a removable splint should be applied. Starched crinoline may be used in preference to plaster of paris, as it is much lighter and therefore much more comfortable.

It is important to note the danger of applying a splint and regarding this as the only indicated treatment. Many patients have been incapacitated by the fibrosis which has resulted from the prolonged and uninterrupted use of splints. So much is this the case that in many

Electrical examination likewise is often valuable to differentiate loss of motion due to severed tendons from paralysis. In the former, galvanic stimulation, followed by a good contraction in the muscle, fails to produce a movement of that segment to which the tendon is attached.

An electric stimulus must reach a certain intensity before it will result in the contraction of a muscle. This minimal current, however, must be prolonged for a certain length of time to produce a response. At "infinite duration" there is a minimum strength below which no contractions occur (rheobasic voltage). As the duration is decreased, the strength must be increased until a point is reached where, no matter how strong the current, no contractions follow. Twice the minimal current which will produce a contraction in unlimited time has been designated empirically as the chronaxia of the tissue. The chronaxia of a human muscle with an intact nerve supply has been found to be 0.00016, whereas that of one whose muscle has degenerated is about 0.01. It was hoped that measurements of the chranaxia would furnish accurate information of diagnostic and prognostic value in peripheral nerve injuries. Although they have served to give precise measurement of the functional value of nerves and muscles in physiology, because of the inaccessibility of accurate instruments and the unreliability of certain others, few data are available which permit of critical judgment of their clinical value. Measurements by the condenser system of Lewis Jones have failed to impress the American investigators with their reliability. More accurate methods, such as the Lucas pendulum, Lapicque's chronaximeter, Strohl's ergometer and Sachs' and Malone's chrooomyometer have appeared to give accurate information in their several investigators' hands. It is possible that they may lead to profitable clinical investigations in the future.

Indications for Treatment

Physical therapy methods hold the first place in the treatment of peripheral nerve lesions. Following a peripheral nerve lesion, the objects to be attained differ somewhat under various conditions. If a primary suture is possible, or if the patient is brought for treatment soon after injury where an operation is not indicated, we aim to prevent deformities and to restore function. When some time has elapsed after injury, and a secondary suture or neurolysis is necessary, the aim is to correct deformities and restore function. The same is true in similar cases not requiring operation.

Operative procedures of suture and neurolysis will not serve to restore function. They only make it possible for the nerves to regenerate. It is conceivable that perfect regeneration might occur in the nerve and an extremity be functionless, because of interphalangeal fibrosis, retraction of capsular ligaments, marked atrophy and fibrosis of muscles, shortening of muscles, spasms of muscles and ankylosed joints.

instances of long delayed restoration of function it was possible to envisage the character of the splint which had been used by the position of the extremity. For example, the ill-advised use of a cock-up splint often caused fibrosis and shortening of the extensors, and ankylosis was present at the wrist. It is equally important that one should not apply a splint devised for one nerve lesion upon an extremity in which a totally different nerve is paralyzed; for example, a cock-up splint should not be applied in the case of a median nerve lesion.

The application of a splint should not blind us to the necessity of other treatment, and it is imperative that electrotherapy, massage, passive movement, etc., be continued throughout the time of immobilization. Although some clinicians believe that no adhesions will form if a splint is applied so that only relaxation is obtained and not over-relaxation, this has not been my experience. Not only must joints not concerned with the movements of the paralyzed muscles be moved daily, but when supported the involved joints must be moved. Certainly no harm can occur from gentle, passive movements sufficient to produce movement but not overstretching. It is well not to produce overcorrection. A position midway between the extent of movement in the opposite direction is by far preferable in most muscles. Only slight extension at the wrist is sufficient to produce rest of the paralyzed and atonic extensor muscles of the wrist. Each individual nerve injury has some general indication which should guide us in the consideration of the splint. Such splints can be better illustrated than described, and the general indications will be discussed and the types of splints illustrated.

Circumflex Nerve.—Injury to this nerve produces a paralysis of the deltoid. The patient is unable to abduct the arm, and the weight of the unsupported arm often results in a subluxation of the head of the humerus and at least a marked stretching of the capsular ligament. The indications are to keep the arm abducted and partly externally rotated. The abduction should not be beyond 60°. The forearm should be flexed and held in moderate supination. Such a splint may likewise be used in upper brachial plexus injuries (Figs. 4, 5).

Ulnar Nerve.—Paralysis of the ulnar nerve is easily recognized by the appearance of the hand, with clawing of the little and ring fingers, inability to grasp objects between the thumb and forefinger because of paralysis of the adductor pollicis, and inability to make a cone of the hand by approximating the tips of the fingers and thumb because of paralysis of the interossei. Lateral movement of the fingers is possible only through supplementary movement, and the patient is unable to innervate the muscles of the hypothenar eminence (Fig. 6).

Although many devices have been constructed for the treatment of ulnar nerve lesions, in general, the majority of cases recover more completely without the use of these cumbersome appliances. They

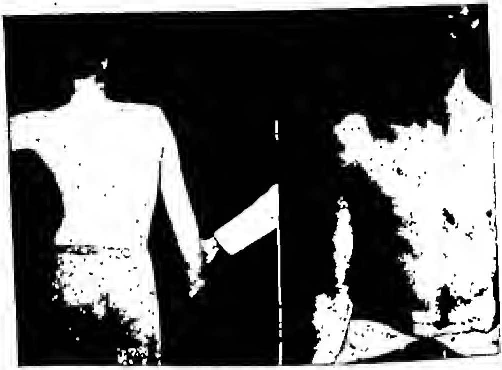


Fig. 4—Paralysis of circumflex nerve.

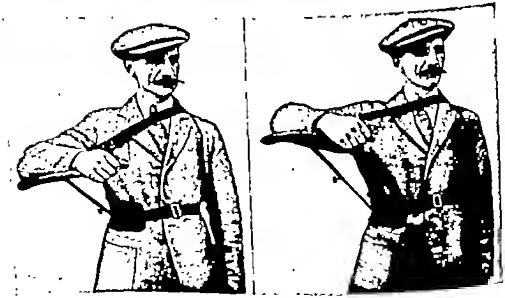


Fig. 5—Splint for circumflex nerve palsy. (From The Diagnosis and Treatment of Peripheral Nerve Injuries, Medical Research Council.)

little and ring fingers may be applied, as illustrated. Extension of the distal phalanges of the little and ring fingers may be defective because of overextension of the proximal phalanges, and a device which prevents these phalanges from overextending is useful in recovering lesions. A narrow strip of metal running diagonally across the palm from the base of the third to the base of the little finger, then bent to continue in the opposite direction over the backs of the proximal phalanges of the little, ring and middle fingers, is often serviceable (Fig. 7).

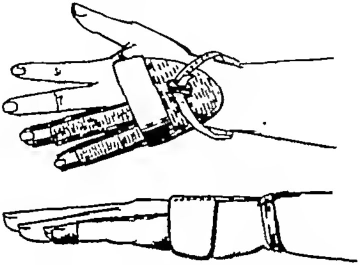


FIG. 7—Splint for ulnar nerve palsy. (Chiray and Dagnan-Bouveret.)

MEDIAN NERVE.—Paralysis due to a lesion of the median nerve produces an inability to appose the thumb to the little finger, to abduct the thumb at *right angles* to the palm, to flex the index finger as in making a fist or clasping the hands, and to flex the distal phalanx of the thumb (Fig. 8).

For the most part, what is true of the ulnar is likewise true of the median nerve. There is but little clawing of the index or middle finger and flexor contracture of the index finger does not occur. The only troublesome complication is a shortening of the adductor of the thumb, and at times it is necessary to hold the thumb in abduction at a right angle to the palm. A light, hollow aluminum ball between the index finger and thumb with the fingers semiflexed assists. A hollow cylinder will serve the same purpose. Occasionally an apparatus, which, by means of a spring, supplants the abduction of the thumb, may be serviceable, although in general springs are unsatisfactory.

COMBINED ULNAR AND MEDIAN NERVE LESIONS.—Combined ulnar and median nerve lesions, when complete, produce inability to perform

interfere with the motility of unparalyzed muscles which suffice to move all of the segments about the joints of the hand. The only disabling complication which follows ulnar nerve lesions is clawing of the little or little and ring fingers. Passive movement commonly suffices to prevent this. When it appears that clawing will result from overaction of the extensor communis digitorum, a simple posterior splint for the

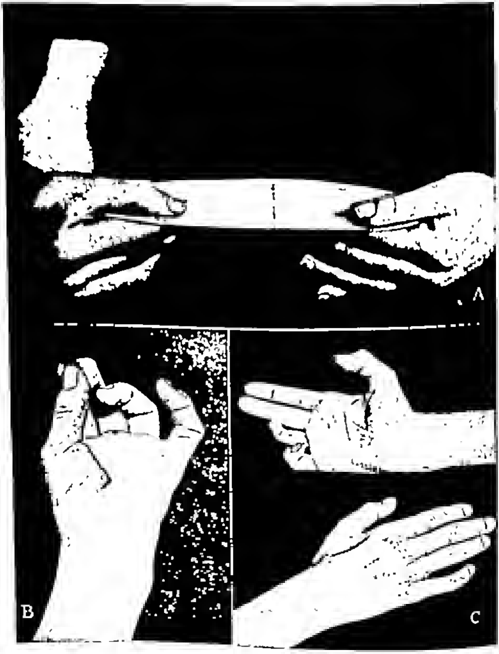


FIG. 6—Ulnar nerve palsy *A*, ulnar paper sign; *B*, inability to make a cone with fingers; *C*, clawing.

any flexor movements of the fingers or hand. Under such a condition, a simple anterior splint supporting the hand in a slightly flexed position suffices. Clawing occurs in all the fingers and counter-pressure should be exerted against the backs of the proximal phalanges. The thumb should be fixed in a position of abduction at right angles to the plane of the palm (Fig. 9).

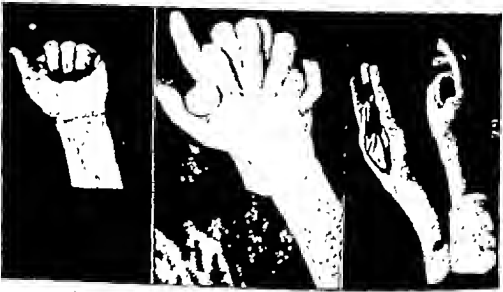
Partial lesions of these two nerves are particularly liable to be complicated by adhesions, shortening and deformity, and require much more attention than complete lesions.

FIG. 10—Radial nerve palsy.

RADIAL NERVE.—The indications in cases of paralysis due to a lesion of the radial nerve are to extend the wrist and the proximal phalanges of the fingers and thumb in a plane with the palm (Fig. 10). The following splint, as described by Buerki and used in the United States Army, is very satisfactory.

"Spring steel wire covered with rubber tubing at all points of pressure and properly bent has been found to make a light and comfortable splint. It will meet the requirements and overcome some of the objections of other types. This splint is made from a piece of No. 11 spring steel wire 35 inches long.

"It is best to start bending the splint on the ulnar side of the arm. Nine inches from the end, the wire is bent upward to form an angle of 140°. From this point the wire extends forward to the junction of



A. B. C.

FIG. 8—Median nerve lesion. A, defect in making fist. B, defect in clasping hands. C, defect in apposing thumb to little finger.

FIG. 9—Combined ulnar and median nerve lesion.

patient from the sharp ends. The palmar arch support is made from No. 20 spring steel wire, covered with rubber tubing, and is attached to the splint by adhesive plaster. The ends are one inch long and are bent in opposite directions from each other to increase the stability of the palmar attachment. The wire first extends downward away from the splint for an inch on each side, and then by a slow curve extends upward to support the palmar arch. A piece of adhesive plaster is now placed on the splint just above the wrist, and folded on itself so that all of the sticking surface is covered. Finally, the canvas band is slipped over the ends coming in contact with the flexor surface of the forearm. This splint can be made in fifteen minutes. It is applied without bandages, and can be readily removed or put on by the patient without assistance." (See Fig. 11.)

Musculocutaneous Nerve Lesions.—Stookey has described a simple and efficient apparatus which may be used to aid in the treatment of lesions of this nerve. The important muscle which is paralyzed is the biceps. Fortunately, there is little or no likelihood of overstretching the biceps or of markedly shortening the triceps because of the mechanics of the elbow joint and the fact that other unaffected muscles act upon both the shoulder and elbow joints. However, at night a mechanical support which keeps the forearm flexed with the hand in full supination should be worn. Stookey's apparatus consists of a broad leather cuff attached to the wrist and dorsum of the hand. The wristband has a metal plate which is shaped to fit the dorsum of the hand and wrist. Supination is maintained by a strap fastened to the wristband over the volar surface of the radius, which passes outward and under the wrist. This strap is then fastened to a collar piece by a pin or snap.

Brachial Plexus Lesions.—Of all the peripheral nerve lesions, none require more constant and efficient mechanical treatment than those of the brachial plexus.

As has been pointed out previously, in general, lesions above the clavicle are injuries of the roots and primary cords, whereas those below the clavicle or in the axilla include the secondary cords and nerve trunks. These latter are frequently accompanied by injuries of the axillary blood vessels. There are two general types of injuries: the Erb-Duchenne or upper root group, which involves the fifth and sixth cervical roots, and the lower root group, or the Klumpke-Déjerine type, which involves the seventh and eighth cervical and first thoracic roots. In the former, the resulting paralysis is extensive and involves the muscles of the shoulder girdle and back as well as muscles of the arm and forearm. In the Klumpke-Déjerine type the paralysis is essentially of the ulnar side of the forearm and all of the muscles of the hand (Fig. 12)

the proximal and middle phalanges of the little finger, where it is bent at a right angle in the same plane. Three-fourths of an inch from here it again receives a right angle bend, but this occurs in a plane at right angles to the previous one. This bend causes the wire to run across the palmar surface of the fingers, and thereby extends the proximal phalanges on the metacarpal bones. A right angle bend in the same plane at the outer side of the first finger, and another bend three-fourths of an inch farther on in a plane at right angles to it, complete

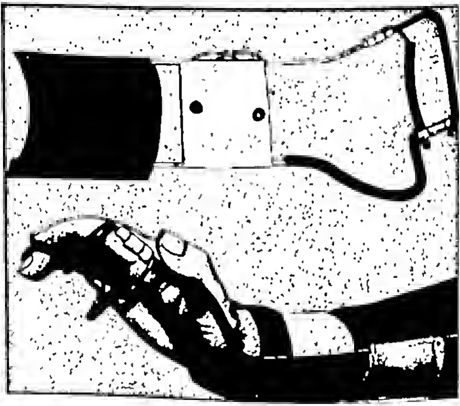


FIG. 11—Splint for radial nerve palsy. (Buerki.)

that part of the splint which keeps the hand in place. The wire then runs backward along the outer side of the first finger until it reaches the point opposite the base of the distal phalanx of the thumb, where it is bent outward at right angles to extend the thumb on the first metacarpal bone. When it reaches the outer side of the thumb, the wire is curved downward and inward to the wrist, following the thumb as nearly as possible in its extended position. The wire is now bent so that it runs parallel to and in the same plane as the wire on the ulnar side of the forearm. The two rubber tubes which protect both the fingers and the thumb from the splint are now slipped into place, and then the ends of the wire are bent on themselves, thus protecting the

nerve high in its course. The branches to the semitendinosus and long head of the biceps are given off at the level of the ischial tuberosities and consequently these muscles are spared. The semitendinosus alone is able to perform the functions of the hamstring muscles to a high degree. It is also able to supplement the action of the gastrocnemius

FIG. 13—Sciatic nerve lesion.

in flexing the leg upon the thigh. However, all the muscles below the knee are paralyzed and the leg is flaccid, while the foot is dropped and in a valgus position. It is necessary to stabilize the leg and foot, to correct the equinovalgus deformity and to overcome faulty deviation of the body weight (Fig. 13).

The most effective and comfortable splint is one based upon the Thomas caliper type. It is light, comfortable and efficient. It should

In those lesions in which the muscles of the back (serratus magnus, rhomboids, levator scapulae) are involved, the deformity is extensive. The compensatory movements of the scapula are diminished or absent. The action of the serratus magnus in fixing the scapula so that the deltoid may act is gone and this must be kept in mind in devising mechanical support. The arm lies adducted with inward rotation. The humerus may soon subluxate and in old neglected cases may be dislocated completely. The coracoid process becomes prominent and the forearm is held in semipronation. Because the entire extremity is rotated inward the palm of the hand may face backward. Left alone without mechanical support these lesions are followed by permanent and irreparable deformity.

A splint must be designed to relax the deltoid and the supraspinatus muscles and at the same time hold the arm in external rotation. The

FIG. 12—Lower brachial plexus lesion.

arm must be held in abduction, preferably at an angle of about 60°, rather than in abduction at 90°. The arm should be rotated externally and the forearm flexed upon the arm and held in moderate supination. Stookey has described a satisfactory splint for these cases. It is made of aluminum and consists of a chest, an adjustable arm and a forearm piece. The arm piece is hinged and may be adjusted to various angles of flexion.

The deformity present in the Klumpke-Déjerine, or lower root, type of paralysis is similar to that seen in combined median and ulnar nerve lesions. A slight straight splint on the volar surface of the forearm, with grooves for each of the fingers, proves quite satisfactory. The straps should be placed so that voluntary extension of the fingers is possible.

SCIATIC NERVE LESIONS.—Paralysis of all the muscles supplied by the sciatic nerve is uncommon even with a complete section of the

side of the foot. This will correct the varus deformity. The ankle joint may be supported if necessary by a leather reinforcement sewed to the shoe. The flat foot may be corrected by an inside plate which should be made to fit individually by molding plaster casts of the foot deformity. The principal aim must be to correct all the deformities and to prevent those which may result from the improper distribution of weight bearing. The patient should be cautioned never to walk without proper support of his foot. A rubber band or metal spring may be attached to the shoe and the upright to aid in replacing the lost action of the extensors.

FIG. 15—Peroneal nerve palsy.

An adequate splint for the foot drop of *peroneal nerve lesions* was used in the United States Army. It had the advantage of simplicity, lightness, and relative service. As described by Buerki, it is made of two pieces of wire weighing but two and one-third ounces. It is serviceable because it not only holds the foot well extended at all times, but it also aids in walking, as it gives the foot the normal flexibility which is lacking in all of these cases. Pieces of bronzed spring steel wire, 25 inches long, have loops three-fourths of an inch long bent on each end, in opposite directions (Fig. 16, Diag. 1). The lower loop is for aid in attaching a wire around the shoes, while that at the top protects the clothing from the sharp wire. To give the splint flexibility, the wire has a one-and-three-quarters turn coil three-fourths inch in diameter

be so arranged with a spring lock at the knee joint that while the patient is sitting the knee may be flexed to an angle of 45°. A sole plate should extend from the heel to the metatarsophalangeal joint and should be attached to the upright so that the foot is held in dorsiflexion. The heel of the shoe should be raised on the inner side and the shoe reënforced there so that the valgus deformity will be corrected and the patient, at the same time, will bear his weight upon the outer side of the foot when he walks. This will aid the weakened arches which naturally accompany these lesions. Another sample splint is shown in Figure 14.

Peroneal Nerve Lesions.—The deformity in these cases is one of foot drop and a varus deformity due to complete paralysis of the

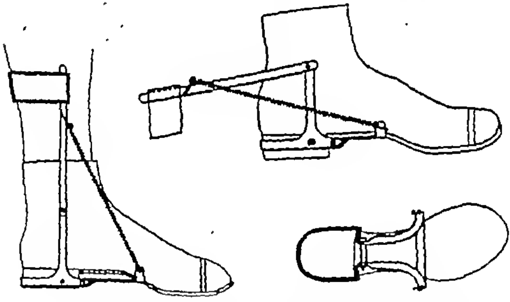


Fig. 14—Splint for sciatic nerve lesion. (Souques, Megivand and v. Domet.)

anterior and lateral muscles of the leg. The os calcis is raised considerably because of the unapposed action of the gastrocnemius. Flat foot occurs because of the lack of support to the arches by paralysis of the peroneal group and extensors attached to the inner side of the foot. A very serious disability in walking exists because of the overaction necessary to keep the toe from scraping the ground (Fig. 15).

It is necessary to splint these patients for more than a toe drop. A light iron strip on the inner side of the leg attached to the shoe with a stop lock will prevent a foot drop. It should be so attached that it raises the foot in dorsiflexion. The iron strip is attached above to a leather band about the leg. The leg should be elevated on the outer side from the heel to the toe to deviate the body weight to the inner

should have a stop lock which will prevent dorsiflexion to more than a right angle. The inner border of the sole and heel should be so raised as to deviate the body weight to the outer side and to correct the valgus position. As in the case of the peroneal deformities, an inside plate fitted individually should be worn to support the weakened arches.

The splints for these last two types of deformities cannot be worn at night, but their main action should be replaced by canvas appliances

FIG. 17—Femoral nerve lesion.

which will effectively prevent overstretching of the paralyzed muscles. Without the use of these nocturnal supports all that has been accomplished during the day may be easily undone.

FEMORAL NERVE LESIONS.—As has been stated, lesions of this nerve are accompanied commonly by injuries to the pelvic vessels and

bent into it six inches from the lower end (*Fig. 16, Diag. 2*). This coil when in place is directly opposite the junction of the sole and heel of the shoe. Two wires, bent as described above, are held in place, one on each side of the shoe, by four pieces of fine piano wire, one piece under the instep, another around the heel at the junction of the upper and the heel, the third under the sole connecting the lower extremities of the wire, and the fourth around the toe between the sole and the upper. The last piece binds the splint permanently to the shoe. It is best to apply the wires in the above order (*Diag. 3*). The splint is completed by a piece of double-ply canvas six inches wide and four

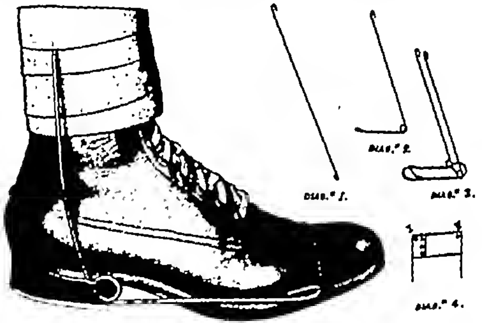


FIG. 16—Splint for peroneal nerve palsy. (Buerkl.)

inches long, and held together by five rivets placed as shown (*Diag. 4*). Rivets I and II keep the splint from slipping through the canvas. The canvas is slipped over the upper end of the splint, around the calf, and the whole is held in place with a special legging. The splint lasts from two to three months.

TIBIAL NERVE LESIONS.—The deformities present in these cases are practically the opposite of those described as the result of injuries of the peroneal nerve lesions. The unopposed action of the peroneal muscles pulls the foot into dorsiflexion and the os calcis is directed downward instead of backward. The foot tends to assume the valgus position and the longitudinal arch flattens because of the paralysis of the tibialis posterior and the small muscles of the sole of the foot.

Mechanical support may be given in the form of a light iron strip on the outer side of the leg attached to the sole of the shoe. This

may become so stretched that an eversion of the lower eyelid may occur (Fig. 18).

The simplest type of support consists of two adhesive straps. The point of pull should be attached to the temporal area and the support-

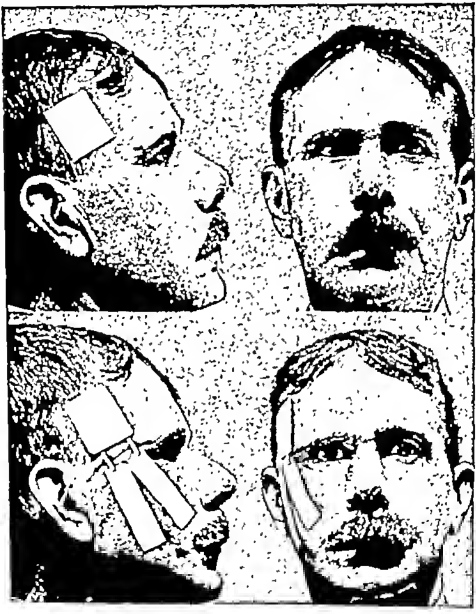


FIG. 19—Splint for facial palsy. (N. S. Yawger.)

ing straps should be attached to the skin about the upper and lower lips. The ends of the two straps may be attached by a rubber band so that an elastic pull upward is maintained. This support must be worn constantly. It is simple and is easily detached during massage, electro-

viscera. Consequently, one is not called upon frequently to provide mechanical support following such a lesion. However, the quadriceps femoris, sartorius and pectineus muscles are paralyzed and there is an inability to extend the leg upon the thigh. A patient with a femoral nerve lesion is unable to stand upon his leg unless the knee is in extreme extension. The knee joint soon becomes so unstable that it may suddenly flex and allow the patient to fall. When walking, the patient usually bends forward and places his hand on the thigh to keep the knee joint securely extended. The tensor fasciae latae may act to hold the joint in fixed extension and then the patient assumes a swinging gait. In old neglected cases a genu recurvatum may develop (Fig. 17).

Mechanical treatment must provide stability to the knee joint and yet prevent hyperextension. A Thomas caliper splint with a spring

FIG. 18—Facial palsy.

lock which allows of flexion of the knee only while sitting is the most efficient type of splint. A broad band in the popliteal space will prevent hyperextension and the occurrence of genu recurvatum.

FACIAL NERVE LESIONS.—The facial muscles must be protected from overstretching and sagging after interruption of their nerve supply, just as other muscles. The mechanical support of these muscles contributes tremendously to the recovery of their action after a nerve supply has been reëstablished. In neglected cases the muscles

serve the functional capacity of paralyzed muscles until sufficient nerve regeneration has taken place to permit of active motion.

The efficacy of this type of treatment has been called into question on a number of occasions. Although since the days of Duchenne neurologists have universally agreed that electrotherapy is of service in hastening the return of function of muscles paralyzed as the result of lesions of the lower motor neuron, some physiologists have decried its usefulness (Langley). On the other hand, many physiologists have determined upon the basis of experimental studies that there is a sound foundation for the belief that electrotherapy is serviceable in the treatment of peripheral nerve lesions. Not only have most of the workers found decreased atrophy in treated cases, but recently Piontkovskiy has shown that a more advanced type of regeneration of the nerve occurs when the denervated extremity is treated by electrotherapy.

Mode of Action.—It is necessary to understand clearly the mode of action of treatment by electricity. It is not concerned with any mysterious force acting directly upon the factors influencing recovery of a nerve or muscle. Stimulation by an electric current of sufficient strength produces a contraction of the muscle. It is this active contraction of the muscle which conserves its bulk and nutrition and keeps the muscle fibers functionally adequate for voluntary movement when regeneration has progressed sufficiently. In cases such as facial nerve paralysis, contractures are diminished and associated movements so often of disfiguring and annoying consequence likewise are prevented. The only requirement of electrotherapy is that it shall produce a contraction of the paralyzed muscle. Obviously, this cannot be brought about by stimulation with the faradic current, as the duration of each shock is too short in relation to the changed chronaxia of the nerve and muscle. Galvanic current must, therefore, be used. It may be used in its simple form of a continuous current, or in the form of sinusoidal currents of various types of waves.

It has been proposed that the continuous current which at the make or break produces a sharp, shock-like contraction is of little value as it does not resemble a normal contraction of the muscle, which it is said is imitated by the contraction ensuing as the result of stimulation by the sinusoidal current. Of course, the criticism that it acts only locally may be met by the statement that larger electrodes should be used. That muscles contract slowly in their normal state has never been shown to be the case by physiologists. The twitch contraction due to electrical stimulation is thought to be analogous to the phasic contraction of all skeletal muscles. It may, I believe, be accepted as a fact that the contraction of a muscle resulting from stimulation by galvanic continuous current is as useful as that produced by any other type of galvanic current. The rapidity of the contractions can produce no harm after the second week following injury or surgical procedures, and during the first two weeks the muscles should be kept practically

therapy and active exercises which are practiced by the patient (Fig. 19).

Corrective Splinting.—When, because of fibrosis of muscles and joints, or because of spasms or contractures of muscles, deformities have taken place, the problem of splinting is a very different one. The indications are to lengthen the shortened muscles and tendons and to mobilize the joints. The splints are devised, therefore, with the view of exerting elastic tension upon the segment of a joint involved in alternating directions for certain periods during the day. So-called

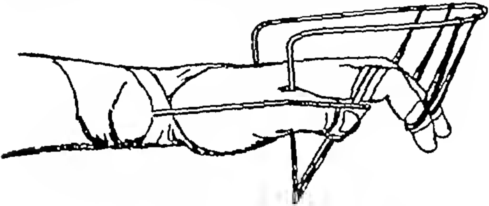


FIG. 20—Apparatus of Dubé. (Chiray and Dagnan-Bouveret.)

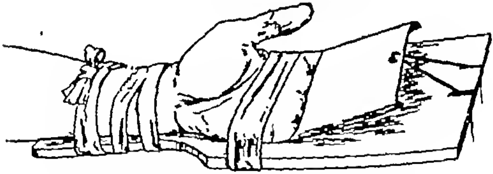


FIG. 21—Apparatus of Cunio. (Chiray and Dagnan-Bouveret.)

fiddle splints, by means of which traction may be applied in one direction and easily reversed, have been most useful. To overcome shortening of muscles, elastic tension is applied to segments of joints to which they are attached in an opposite direction. A simple method of lengthening the lumbricales is shown in Dubé's apparatus (Fig. 20), and of the flexors of the thumb and fingers, in Cunio's splint (Fig. 21).

Electrotherapy.—The indications for electrotherapy are to prevent atrophy of muscles and fibrosis, to increase nutrition and to con-

a movement with the extremity in a position of foot drop, but if the patient rests the leg on a board at the outer surface, dorsal flexion may occur. The patient's extremities must be fully supported and the segments about joints so supported that movement is not impeded by gravity.

VALUE OF CONTRACTIONS.—Contractions of muscles produced by electric stimulation are a valuable adjunct to reëducation and active motion. Although the patient may not be able to produce extension at the wrist voluntarily, the hand may be held in this position after electrically produced extension has occurred. A voluntary contraction of a muscle may be possible after it has been produced by electrical stimulation, and the patient should be required to attempt such a movement during the period of treatment. Of course, one should always keep in mind the law of regeneration. When it is remembered that the extent of regeneration of the nerve after section and suture is one millimeter a day, it is futile to have the patient attempt active movement before the fourth month in such cases. In severe compressions in which recovery is taking place without operation but which are associated with complete degeneration of the distal segment, the same conditions hold true. Care must be exercised in treating areas of skin in which sensation has been destroyed, as burns are readily formed, and ulceration, once occurring, is difficult to heal.

When the nerve and muscle have recovered sufficiently to contract to faradic stimulation, both forms are advisable, the latter to produce more prolonged or tetanic contractions. An apparatus which permits of stimulation by gradual increase and diminution of current, such as is possible with one Bristow coil, is valuable as it is less painful. Here again it is necessary to state that during the period of severe degeneration the faradic current will not produce a contraction of the muscle, and no contraction means no treatment.

Sinusoidal current and other forms of wave currents have only the advantage of relative painlessness. There is a seeming advantage in the fact that at times a larger electrode is used and rhythmic contractions are produced in large muscle groups. This is a disadvantage and care should be exercised to stimulate only the paretic muscles.

PASSIVE MOVEMENT.—As Langley has pointed out, intermittent passive or active stretching forces lymph, and so presumably metabolic products, from the muscles. This, of course, should be an advantage. Moreover, such active or passive movements have a distinct influence on the formation of connective tissue. It is said that there is a visible increase of connective tissue in microscopic preparations of a muscle three weeks after section of its nerve. Part of the last contractures may be due to the shrinkage of this newly formed tissue which is soft and extensible. Active or passive movements of the denervated muscles will stretch the developing fibers so that when they do shrink there

at rest, as they are fragile and are easily bruised. After this period sudden contractions are just as useful as slow ones. The force of the contraction can, of course, be modified by the strength of the current. Galvanic continuous stimulation is often painful; therefore, other types of waves are useful as they are relatively painless and can be used to advantage in children and sensitive patients. It is necessary to remember that the contraction of a muscle occurs only upon making and breaking the current. Therefore, it is needless to treat the muscle by prolonged stimulation and the current should be applied with very short makes and immediate breaks of the current by using a suitable electrode.

The stimulation may be obtained by using bipolar or unipolar methods. In the former both poles are applied to the muscle which it is desired to stimulate. In the latter an indifferent electrode of a large size is placed elsewhere upon the body, as described under electrodiagnosis. During the first few months following injury, while the muscles are hyperirritable, and an increase of direct myotatic irritability may be demonstrated by percussion, unipolar stimulation will produce contraction in the muscles most affected by the weakest currents, because of longitudinal stimulation. Care must be exercised, therefore, not to produce too great fatigue in these muscles. One must always keep in mind the fact that in many cases deep muscle sense is defective and the patient is unable to tell when the muscles are fatigued. After the first few months, the muscles most affected become less irritable to stimulation and unipolar stimulation produces a spread of current to unparalyzed muscles, which may alone contract, to the injury of the patient. At this time bipolar stimulation is of greater value. A clear knowledge of anatomy and function of muscles is necessary to produce the most benefit. Particularly is this true of the small hand muscles. Inasmuch as the nerve itself is not irritable to stimulation, the electrodes need not be placed upon the motor points of the muscles, as is the case in paralysis of the upper motor neuron. However, even the muscle may contract more readily at these points.

Although polar inversion is not always the rule in degenerated muscles, it is sufficiently so that the positive pole should be used as the active electrode. It is also the least painful.

In the treatment of ulnar and median nerve lesions, the small hand muscles—the interossei, lumbricales, adductor and opponens of the thumb, and the muscles of the hypothenar eminence—require the greatest attention.

In producing contractions of the paralyzed muscles, care must be exercised to prevent the force of gravity from acting against the contracting muscles, not only to prevent the detection of movement of segments around the joints, but to prevent fatigue. Upon stimulating the extensors of the wrist no movement may be seen if the wrist is held dependent, whereas if it is supported upon a board at its ulnar border, extension may take place. The extensors of the foot may not produce

tion of the extremity which is maintained by a splint should be held throughout the treatment. There never should be stretching upon the denervated muscles. Massage is begun with a period of rhythmic superficial stroking to obtain further relaxation. This may be given in either direction, whichever is more pleasing to the patient, and the pressure must be so gentle that even centrifugal stroking will not interfere with the circulation. Following this gentle stroking, all of the muscles of the extremity should be massaged with a centripetal motion to increase the venous and lymphatic circulation. More pressure should be used than previously but care should be taken not to injure the paralyzed muscles by compressing them against the bones. This may be increased gradually until the massage consists of a gentle kneading.

If superficial scar tissue is present, friction massage should be used. This is obtained by pressing deeply and moving the hand in a circular direction. The outer tissues should be moved over the underlying structures with a minimum of movement on the surface. If the scar is dry, a lubricant may be used at the end of the friction massage, but its use in the beginning makes deep friction impossible. If adhesions and contractures are present, they must be stretched slowly and gradually. Stretching must not be carried to the point where it causes pain or tenderness following the treatment and the movement of returning to the original position must be made as slowly and as carefully as the stretching movement. Gentle kneading of the contracted muscles and friction over the ankylosed joints may be performed during this procedure.

Reëducation.—The indications are to train the patient to reproduce voluntarily the movement which has just been provoked electrically or by passive movement. This is the most important part of physical therapy, particularly because not only motor regeneration must be complete but sensory regeneration as well, in order to effect accurate movement. A certain type of deep sensibility that deals with joint sense is among the last to recover, and often never recovers completely. An ataxia results, even if motor regeneration is perfect. It is necessary, therefore, to treat this ataxia by reëducation.

The extremity of the patient must be so supported that the force of gravity does not act against the contraction of the muscle. At times it is advisable to have the extremity supported by a sling, or a freely swinging board suspended by spiral springs and counterweighted so that the least amount of power is necessary to produce movement. Exercises may be performed to great advantage with the extremity immersed in water. Finally, the extremity may be placed upon a powdered board so tilted that the above indications are met. The patient is directed to perform a movement, and at the same moment the operator slowly, passively performs the movement. As each normal movement is attempted, the patient may be directed to perform the

may be less tendency to a contracture. The cut ends of a nerve may become rather fixed to the surrounding connective tissue so that movements may cause a greater pull upon the nerve. However, Langley has shown that in this presuture period the tension so placed upon a nerve is not sufficient to cause a rupture of the degenerating fibers.

In many operations it is necessary to fix the limb in a flexed position to permit the cut ends of the nerve to be brought into end-to-end apposition. In such instances passive movements designed to bring the limb into its normal position may be begun about two weeks after the suture has been made. Miller and Lewis have shown experimentally that the tensile strength of a suture line is as great at the end of that time as it is weeks later. This is an important fact which allows passive and active movements to be instituted before formidable ankyloses and contractures have occurred.

Passive exercises may be carried out very well in conjunction with massage. They help to stretch contractures which have already occurred and to prevent those which invariably occur in a denervated muscle. They also increase the range of motion in an already stiffened joint and help to keep a mobile joint active so that when the time comes it is ready to perform its part in an effector mechanism. Finally, such movements help to reëducate the muscles in performing normal movements. These exercises should be carried out slowly and gently and never with quick, jerky movements. Each separate passive exercise should be individualized and the patient should be required to make the attempt to perform the movement simultaneously or to attempt to hold the part in the position imposed upon it.

In many instances active exercises may be employed to great advantage. For example, a median or ulnar nerve lesion at the wrist does not affect the innervation of the long flexor muscles of the fingers and the wrist. Unfortunately, it is common to find the phalangeal and carpal joints ankylosed or the muscles atrophied simply from disuse. As Kanavel has pointed out, in practically every case of joint or muscle injury, passive motion of the injured part with the help of the sound member, combined with voluntary exercises, will accomplish a great deal towards the restoration of function if the patient has sufficient intelligence and energy.

Massage.—Before massage is begun the part should be exposed to heat for twenty to thirty minutes to obtain as much relaxation as possible. Radiant heat, the infra-red light, hot packs or a whirlpool bath of warm water are all useful but should be used with extreme care, particularly because of the ease with which it is possible to burn the skin of a denervated area. The whirlpool bath is preferable because the motion of the water acts as a gentle massage which is pleasing to the patient and gives relief from pain.

Before beginning massage the extremity must be placed in a comfortable position with all the muscles completely relaxed. The posi-

CHAPTER EIGHT

PHYSICAL THERAPY IN INFANTILE PARALYSIS

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Introduction

Poliomyelitis is a specific infectious disease, the causative agent of which is thought to be a filtrable virus. Although adults may be stricken with poliomyelitis, the disease is primarily one of young children, appearing rarely under one year, but reaching the peak incidence at about the five-year-age level. A marked seasonal incidence is apparent in the consistent recurrence of the disease in the late summer and early fall. The disease is most common in temperate climates.

In order to follow the course and treatment of anterior poliomyelitis carefully, the disease is best considered in four stages:

The *first*, or *acute*, *stage* includes the constitutional symptoms, and the preparalytic and paralytic phases. Its treatment should be wholly medical.

The *second stage* begins as soon as the temperature becomes normal. At this stage sensitiveness is still present, and the muscles show paralysis or weakness. Early orthopedic treatment for the prevention of deformity should start at this time, but no active treatment, such as massage and muscle training, until the sensitiveness has disappeared. It is during this second stage that most of the spontaneous recovery takes place.

The *third*, or *convalescent*, *stage* starts when the sensitiveness is over and includes that period when the muscles make the greatest gain in power. Active muscle training should be carried on faithfully.

The *fourth*, or *chronic*, *stage* is the stage after the muscles have finished their rapid gain. A certain proportion will have recovered to such an extent that no treatment is necessary other than occasional supervision. The remainder will still need orthopedic care, and the majority will still obtain benefit from muscle training and massage. This benefit will be shown both in actual, although slow, gain in muscle strength and in an improved use of the body as a whole in getting around and taking part in normal activities. Furthermore, badly affected muscles lose tone and function, and slight contractures develop into fixed deformities, if regular treatment is neglected, even in the chronic stage.

movement on the normal side as well. If electricity is used to produce a movement, the technic is the same.

Although actual movements of muscles paralyzed as the result of a complete section of the nerve do not occur before the fourth month, these exercises may be begun after the third month. Whether supplementary movement, which at times develops during treatment, always retards recovery of paralyzed muscles is a moot question, and if the movement is adequate to function as in paralysis of the deltoid, it makes little difference to the patient. Care must always be exercised to prevent fatigue in the paralyzed muscle.

Occupational Therapy.—Gymnastics of various kinds, Frenkel's movements, etc., are valuable. Particularly valuable in consideration of the long-time required to effect recovery is occupational therapy. The type of occupation should be devised to fulfill two requirements: first, that which will hasten recovery and, second, that which, if recovery does not take place, will be of benefit to the patient in the use of the extremity. The handles of tools are so constructed as to afford support and exercise to the weakened muscles. Hammers, screwdrivers, chisels, saws, planes, all lend themselves well to exercising the upper extremities, and foot pedals of various kinds can be used for the lower ones. The small hand muscles are assisted in recovery by typing, basket weaving, rug making and fretwork. By the combined use of all the methods outlined, a functional recovery may be brought about which justifies the surgical treatment, patience and time expended.

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While the treatment of the acute stage is entirely medical, some knowledge of it is desirable in order to understand the later stages.

First, or Acute, Stage *

The disease usually develops in the patient first as a general systemic process, of short duration, in which the child is only mildly ill with slight fever and some variable indefinite symptoms referable to the upper respiratory tract or the gastro-intestinal tract. The patient recovers from this mild indisposition, which is frequently entirely over-

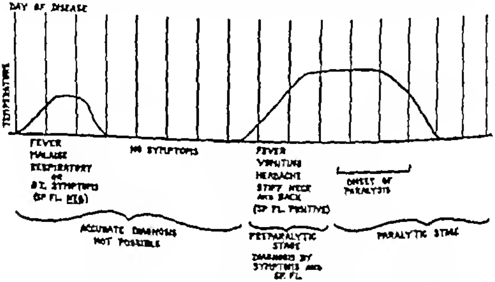

Fig. 1.—Chart showing symptoms and signs in the febrile stage of poliomyelitis.

looked, appears well for a period up to four or five days and then is again taken ill, this time with systemic symptoms plus evidences of central nervous system involvement. Fever, headache, rigidity of the neck and back and a degree of prostration out of accord with the elevation of temperature usually characterize this stage. The face is flushed and the expression anxious. The child is usually mentally clear and alert if disturbed, but lapses into a drowsy state if left alone.

Whereas spinal puncture done during the first stage of the disease yields normal fluid, spinal puncture during the second stage (or stage of nervous system involvement) yields fluid which confirms the extension of the process to the central nervous system. The spinal fluid is under increased pressure at the first lumbar puncture (although subsequent examination may show a normal or even reduced pressure). The fluid is colorless, clear or ground glass, rarely turbid, and there is present a readily demonstrable increase in the globulin. Sugar is present in normal amounts. Cells are present in numbers ranging from

* I am greatly indebted to Dr. Charles F. McKhann for the description of the acute stage.

fifty to several hundred, usually lymphocytic or monocytic in type. Occasionally, and especially very early in the meningitic stage, the fluid may be quite turbid, and the cell count may run as high as 1500 to 2000 per cu. mm. In these cases the cells may be largely polynuclears. The high cell counts tend to fall rather rapidly, accompanied by a change in the types of cells to those of the mononuclear series.

These evidences of acute infection with meningeal involvement last but a few days. Yet in these few days of febrile disease the damage is done to the central nervous system, and the full basis of paralysis is established.

The first appearance of paralysis is usually 36 to 48 hours after the onset of the meningeal stage, with the maximum extent of paralysis reached usually within 48 to 72 hours after the first demonstrable weakness. With the fall of the temperature to the normal level, the danger of further damage to the central nervous system, or further extension of paralysis becomes remote.

Death from poliomyelitis in the acute stage of the disease is due usually to failure of the respiratory mechanism brought about presumably in one of three ways:

(1) In dorsal involvements directly, by paralysis of the primary respiratory muscles, the intercostal muscles and the diaphragm.

(2) In bulbar types indirectly, in patients with paralysis of the pharynx, by the collection of mucus or vomitus about the glottis, causing, either by actual obstruction or by initiating spasms of the glottis, constantly interrupted, shallow and irregular respiratory efforts.

(3) In bulbar types, in addition to pharyngeal paralysis, directly by disturbance of the nerve centers in the medulla which control respiration.

The last few years have brought definite advances in the treatment of these dangerous forms of the disease, advances which fall in large measure into the field of physical therapy. For the treatment of the first type of respiratory failure, involvement of the intercostal muscles or the diaphragm, the Drinker respirator has proved quite effective. In the treatment of bulbar forms of the disease, without intercostal or diaphragmatic involvement, where both the second and third mechanisms of interference with respiration may be operative, the results obtained from the use of the Drinker respirator have not been very encouraging.

However, in view of the observation that patients with bulbar involvements, if they survive, show a most remarkable return of function in the paralyzed muscles of the pharynx, every effort should be made to maintain life in these patients suffering from high cord or brain stem involvement. Much can be accomplished of benefit to patients who have pharyngeal paralysis not complicated by central interference with respiration. Inasmuch as patients suffering from pharyngeal

paralysis may succumb to interference with respiration due to collection of mucus or vomitus in the pharynx, or may develop a bronchopneumonia due to the aspiration of this material, the indication is to keep the pharynx dry and free from secretions. This can be facilitated by having the patient lie on his side or on his face and by elevating the foot of the bed. Aspiration of the pharynx for the removal of secretions may be necessary. Patients with bulbar involvement show, in the febrile stage, a tendency to vomit, so that frequently it seems necessary to rely on parenteral fluids, avoiding anything by mouth in these patients until the temperature becomes normal. After the temperature drops, the nutrition of the patient may be maintained by gavage feedings. In the majority of patients the swallowing function returns in a few days, though occasionally postural drainage, aspiration of the pharynx, and gavage feeding may be required for several weeks. Even in these prolonged cases return of function of muscles supplied from the bulbar regions of the spinal cord has been surprisingly good.

Patients who have shown, in addition to pharyngeal paralysis, the spasmodic, irregular breathing suggesting central interference with respiration have been treated in a variety of ways other than in the Drinker respirator, usually without demonstrable benefit. The procedures which have been tried include repeated spinal fluid drainage and the use of hypertonic salt or glucose solution intravenously.

Extent of Paralysis and Return of Function

Frequently the extent of the paralysis in patients during the acute febrile stage of poliomyelitis is not immediately and fully appreciated. The pathologic lesion, however, has reached its maximum, and failure to determine the exact extent of the paralysis is due more to the difficulties inherent in the careful muscle examination of a severely ill patient than to the absence at this time of paralysis which is discovered only subsequently. Also, before or with the development of paralysis there appears, in the majority of cases, the muscle tenderness which is recognized as a characteristic of the disease and which interferes materially with an accurate muscle examination.

With the passing of the acute febrile stage there passes the peak of the pathologic process, and thereafter any change is usually in the direction of improvement. As noted before, bulbar types of involvement are especially prone to show this rapid recovery.

A brief statement of the pathologic process aids materially in our understanding of the clinical course and the outlook for return of function in the involved members. When the virus invades the central nervous system it incites a marked edema of the cord with considerable perivascular infiltration, the development of minute hemorrhages, and almost immediate injury of the anterior horn cells. Some of the nerve cells of the anterior horn appear to be destroyed specifically by the virus and removed by infiltrating phagocytes. Other cells apparently

are not reached by the specific agent but are seriously impaired in their function by interference with the blood supply, probably in turn a result of the extensive edema.

With the subsidence of the acute process, the edema diminishes, the hemorrhages resorb, and the motor nerve cells which have remained viable gradually resume their normal functions. But the cells which are no longer viable continue to degenerate, while groups of phagocytic cells collect to remove this débris. When in a given level of the cord a few cells only are destroyed, the outlook as regards considerable return of function should be good. In very severe involvements all of the motor cells at certain levels may be destroyed, and in a few weeks a cavity in the cord may develop where once was a portion of the anterior horn. Obviously in cases where this type of extensive degeneration has been found at necropsy, had the patient survived, little could have been hoped for in the way of recovery of paralyzed members.

Unfortunately exact determinations of the extent of involvement can be made only by pathologic examination. Clinically the number of patients who show some return of function in a paralyzed part is so large as to justify an optimistic attitude as regards some return of function in *all* cases and the acceleration of this return by proper physiotherapeutic procedures. In the paralyzed part in which the passage of time has demonstrated the complete destruction of the nerve supply and the failure of the natural regenerative process, the obligation to resort to orthopedic reparative procedures is obvious.

Second Stage

EARLY ORTHOPEDIC TREATMENT

This stage begins as soon as the acute febrile stage is over, when the cases are definitely paralyzed or weakened. About 80 per cent of the patients will show sensitiveness at this time, although others apparently never have any sensitiveness.

The objects of treatment at this stage are the prevention of early deformities and the relief of the sensitiveness. The sensitiveness can be most easily combated by hot packs, given two or three times a day for about fifteen minutes. If both arms and legs are sensitive, the entire body should be wrapped in wet blankets or towels which have been placed in hot water and wrung out. A rubber sheet outside will keep the heat in and protect the bed. If only the legs are tender, the wrappings may extend from the waist down. The heat should not be intense enough to be debilitating, or to require the use of ice applications to the head. Dry heat, from electric pads, hot-water bottles or radiant light bakers, may be applied to the sensitive areas, but moist heat has seemed to the writer to be more effective in lessening the sensitiveness due to infantile paralysis.

This stage may last from a few weeks to two or three months. No massage should be given during it. Complete immobilization in splints, or in a plaster bed, will aid in the relief of the sensitiveness. Unless the case is seen within a few days of onset, the knees and thighs may be already flexed on the body and resist extension. It may be necessary to immobilize in this position at the start, if the flexion and pain are severe, and gradually bring the legs down as the pain subsides.

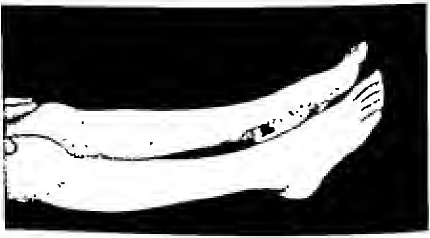

FIG. 2.—Equinus assumed in recumbent position with weak dorsiflexors.

FIG. 3.—Copper wire splint for prevention of deformity in recumbent cases.

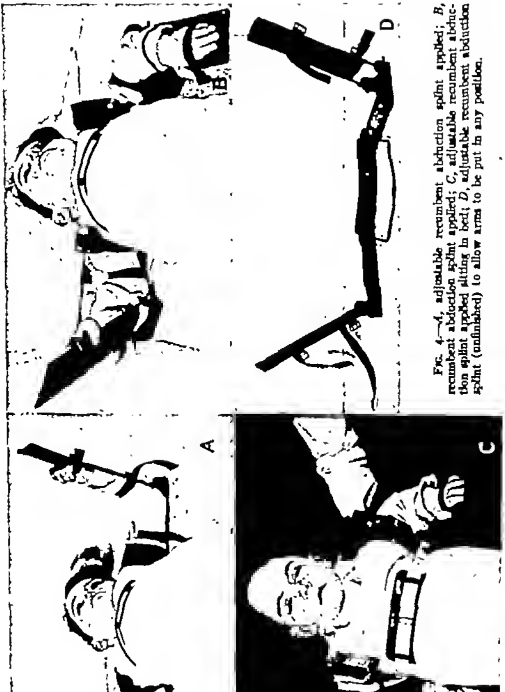

FIG. 4.—A, adjustable recumbent abduction splint applied; B, recumbent abduction splint applied; C, adjustable recumbent abduction splint applied sitting in bed; D, adjustable recumbent abduction splint (unfinished) to allow arms to be put in any position.

In the nursing care of the patient particular attention should be paid to the condition of the skin to prevent bed sores or chafing from the splints. A daily sponge bath may be given, followed by a light alcohol rub, but the sensitive joints should be moved as little as possible, and no brisk rubbing should be given with the alcohol. Any deep massage, or too much passive motion, may increase the sensitiveness and prolong this stage.

If the limbs are completely immobilized for any length of time in the corrected position, the sensitive muscles will shorten in this position, and joint motion will be lost. Light passive motion of the knees and hips should be given twice daily, flexing each to the point of pain once or twice. Otherwise when active treatment is started, it will be found that the patient can not be sat up on a chair because of the tightness of the posterior gluteal muscles at the hip, and the knees can not be bent on account of the tight knee extensors, which can not be easily stretched out without permanent damage to the muscles. The joints of the arm should be treated in the same way.

The general practitioner can prevent deformities and hold the legs and trunk in their normal position by means of sandbags, or a box to hold the feet at right angles, with the body kept in a straight position by pillows. A patient with sensitive shoulders should not be allowed to keep the arms close to the chest and the elbows flexed. A small pillow in the axilla will help to prevent adduction contractures if a splint is not available, and a bandage around the wrist may be pinned to the bed to keep the elbow in partial extension.

It is far better to utilize pillows even though they must be adjusted frequently to maintain the desired position, than it is to put on a solid plaster cast and leave the patient in it for any length of time. This interferes with the return of muscle power and produces stiff joints.

Rest is the essential thing during this period, and the patients should be moved as little as possible except for necessary nursing care; a Bradford frame should be used if it is necessary to carry them. No increase in muscle activity should be allowed before a muscle examination is made.

Third, or Convalescent, Stage

When the sensitive stage is over, active physical therapy can be started.

At this time, an examination shows either a definite flaccid paralysis of the muscles affected or, if a mild case, some degree of weakness. The reflexes may or may not be present, according to the extent of the damage in the spinal cord, but they are never increased in this stage. Some muscles may be contracted from overbalance, or from habitual position, but they are never spastic. The patient's coördination in controlling the muscle power which remains is never affected. If he has the muscular strength to perform the desired motion, he will execute it, and there will be no ataxic or uncoördinated movements.

The mentality is never impaired, and as a general rule the patient's attitude is hopeful and coöperative, although some of the older ones may have more or less depression as they come to realize the extent of their affliction.

The circulation of both legs is decreased during the period while the patient is being kept in recumbency, and atrophy will follow if the circulation is not kept up. Besides this effect of inactivity on the circulation of both normal and affected muscles, there is in many cases some vasomotor disturbance which shuts down the blood supply to a great degree. As a result of this, we may find later a marked atrophy of the muscles and considerable shortening in a leg where there is very little loss of power, while another case with marked muscular involvement may have no shortening at all. However, the majority of cases with severe leg paralysis eventually show both atrophy and shortening.

While some cases may show some loss of sensation during the acute stage and a few have incontinence or retention of urine, these symptoms are never permanent and, if present, are a sign of some condition other than infantile paralysis.

The classic signs of some other forms of paralysis, such as shiny skin, deformed nails, lack of sensation or anesthesia to heat, pain, touch, etc., are never present in infantile paralysis.

This period when the sensitiveness has recently disappeared is the period of most rapid spontaneous recovery. Many cases show a remarkable spontaneous recovery in power during the first few weeks after the onset, even changing from complete paralysis to normal strength without any treatment whatever. This is explained by the fact that the early paralysis was due to pressure on the nerve centers by the edema in the spinal cord, without, however, any destruction of these motor centers. With the disappearance of the edema, the nerve cells resumed their normal function, and the muscles ceased to be paralyzed. This spontaneous recovery is often attributed by parents and irregular practitioners to all sorts of batteries, lights and applications, which have no value in themselves.

Before any intelligent physical therapy treatment or reëducation of the affected muscles can be started, a complete muscle examination must be made to show the extent of paralysis and the comparative strength of the different muscle groups. A muscle examination can be made only by someone who has a thorough knowledge of functional anatomy and knows the relative normal strength of the different muscles examined. Any person without this knowledge of functional anatomy is not competent to make a complete muscle examination nor to carry out intelligent treatment.

It is inexcusable for a physician to turn a case over to a masseuse or a physical education instructor without special training and experience in this special branch of physical therapy. It is not sufficient for him to ask a patient sitting on the edge of a table to extend his

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The classic signs of some other forms of paralysis, such as shiny skin, deformed nails, lack of sensation or anesthesia to heat, pain, touch, etc., are never present in infantile paralysis.

This period when the sensitiveness has recently disappeared is the period of most rapid spontaneous recovery. Many cases show a remarkable spontaneous recovery in power during the first few weeks after the onset, even changing from complete paralysis to normal strength without any treatment whatever. This is explained by the fact that the early paralysis was due to pressure on the nerve centers by the edema in the spinal cord, without, however, any destruction of these motor centers. With the disappearance of the edema, the nerve cells resumed their normal function, and the muscles ceased to be paralyzed. This spontaneous recovery is often attributed by parents and irregular practitioners to all sorts of batteries, lights and applications, which have no value in themselves.

Before any intelligent physical therapy treatment or reëducation of the affected muscles can be started, a complete muscle examination must be made to show the extent of paralysis and the comparative strength of the different muscle groups. A muscle examination can be made only by someone who has a thorough knowledge of functional anatomy and knows the relative normal strength of the different muscles examined. Any person without this knowledge of functional anatomy is not competent to make a complete muscle examination nor to carry out intelligent treatment.

It is inexcusable for a physician to turn a case over to a masseuse or a physical education instructor without special training and experience in this special branch of physical therapy. It is not sufficient for him to ask a patient sitting on the edge of a table to extend his

HARVARD INFANTILE PARALYSIS COMMISSION

300 LONGWOOD AVENUE, BOSTON

Number.................... Date .... Clinic ....

Age........

Name .... Sex .... Birthday...

Residence .... Telephone ....

.... Birthplace ....

.... Race ....

Father's Name .... Birthplace .... Occupation ....

Mother's Name .... Birthplace .... Occupation ....

Doctor's Name .... Address ....

Date of Onset .... Date of Paralysis ....

Serum .... Initial Symptoms ....

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Distribution of Initial Paralysis...

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Sensitiveness (where) ....

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Previous Treatment ....

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Operation ....

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FIG. 5.—History sheet used in the After-Care Treatment Clinic of the Harvard Infantile Paralysis Commission.

HARVARD INFANTILE PARALYSIS COMMISSION

No..................

Patient's Name ....

Left Arm			Right Arm	
		Contractions and Deformities		
....	....	Shoulder	....	....
....	....	Elbow	....	....
....	....	Wrist	....	....
....	....	Fingers	....	....
....	....	Anterior Deltoid	....	....
....	....	Posterior Deltoid	....	....
....	....	Upper Trapezius	....	....
....	....	Middle Trapezius	....	....
....	....	Lower Trapezius	....	....
....	....	Serratus Magnus	....	....
....	....	Rhomboids	....	....
....	....	Latissimus Dorsi	....	....
....	....	Clav. Pect. Major	....	....
....	....	Stern Pect. Major	....	....
....	....	Outward Rotators	....	....
....	....	Biceps	....	....
....	....	Triceps	....	....
....	....	Supin. Brev.	....	....
....	....	Pronators	....	....
....	....	Flexor Carpi Rad.	....	....
....	....	Flexor Carpi Uln.	....	....
....	....	Extensor Carpi Rad.	....	....
....	....	Extensor Carpi Uln.	....	....
....	....	Flex. Prof. Digit.	....	....
....	....	Flex. Sub. Digit.	....	....
....	....	Finger Ext.	....	....
....	....	Lumbricales	....	....
....	....	Dors. Inteross.	....	....
....	....	Abd. Min Digit.	....	....
....	....	Palm. Inteross.	....	....
....	....		....	....
....	....	Oppon. Poll.	....	....
....	....	Abd Poll.	....	....
....	....	Thumb Flex.	....	....
....	....	Thumb Ext.	....	....
....	....		....	....
....	....	Upper Arm	....	....
....	....	Lower Arm	....	....

FIG. 6.—Arm examination sheet used in the After-Care Treatment Clinic of the Harvard Infantile Paralysis Commission.

HARVARD INFANTILE PARALYSIS COMMISSION

300 LONGWOOD AVENUE, BOSTON

Number.................... Date .... Clinic ....

Age.........

Name .... Sex .... Birthday...

Residence .... Telephone ....

.... Birthplace ....

.... Race ....

Father's Name .... Birthplace .... Occupation ....

Mother's Name .... Birthplace .... Occupation ....

Doctor's Name .... Address ....

Date of Onset .... Date of Paralysis ....

Serum .... Initial Symptoms ....

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....

Distribution of Initial Paralysis..

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Operation ....

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HARVARD INFANTILE PARALYSIS COMMISSION

No..................

Patient's Name ....

Left Arm			Right Arm	
		Contractions and Deformities		
....	....	Shoulder	....	....
....	....	Elbow	....	....
....	....	Wrist	....	....
....	....	Fingers	....	....
....	....	Anterior Deltoid	....	....
....	....	Posterior Deltoid	....	....
....	....	Upper Trapezius	....	....
....	....	Middle Trapezius	....	....
....	....	Lower Trapezius	....	....
....	....	Serratus Magnus	....	....
....	....	Rhomboids	....	....
....	....	Latissimus Dorsi	....	....
....	....	Clav. Pect. Major	....	....
....	....	Stern. Pect. Major	....	....
....	....	Outward Rotators	....	....
....	....	Biceps	....	....
....	....	Triceps	....	....
....	....	Supin. Brev.	....	....
....	....	Pronators	....	....
....	....	Flexor Carpi Rad.	....	....
....	....	Flexor Carpi Uln.	....	....
....	....	Extensor Carpi Rad.	....	....
....	....	Extensor Carpi Uln.	....	....
....	....	Flex. Prof. Digit.	....	....
....	....	Flex. Sub. Digit.	....	....
....	....	Finger Ext.	....	....
....	....	Lumbricales	....	....
....	....	Dors. Inteross.	....	....
....	....	Abd. Min. Digit.	....	....
....	....	Palm. Inteross.	....	....
....	....		....	....
....	....	Oppon. Poll.	....	....
....	....	Abd. Poll.	....	....
....	....	Thumb Flex.	....	....
....	....	Thumb Ext.	....	....
....	....		....	....
....	....	Upper Arm	....	....
....	....	Lower Arm	....	....

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300 LONGWOOD AVENUE, BOSTON

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HARVARD INFANTILE PARALYSIS COMMISSION

No..................

Patient's Name ....

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		Contractions and Deformities		
		Shoulder		
		Elbow		
		Wrist		
		Fingers		
		Anterior Deltoid		
		Posterior Deltoid		
		Upper Trapezius		
		Middle Trapezius		
		Lower Trapezius		
		Serratus Magnus		
		Rhomboids		
		Latissimus Dorsi		
		Clav. Pect. Major		
		Stern. Pect. Major		
		Outward Rotators		
		Biceps		
		Triceps		
		Supin. Brev.		
		Pronators		
		Flexor Carpi Rad.		
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		Abd. Poll.		
		Thumb Flex.		
		Thumb Ext.		
		Upper Arm		
		Lower Arm		

FIG. 6.—Arm examination sheet used in the After-Care Treatment Clinic of the Harvard Infantile Paralysis Commission.

No. ....

Patient's Name ....

Cannot walk, walks unaided, with braces, crutches and corset.

Characteristic Gait ....

Scoliosis ....

	Left Leg	Contractions and Deformities	Right Leg	
		Hip		
		Knee		
		Ankle		
		Facial Orbit		
		Facial Mouth		
		Anterior Neck		
		Posterior Neck		
		Back		
		Respiration		
		Quadratus Lumborum		
		Anterior Abdominals		
		Lateral Abdominals		
		Gluteus maximus		
		Hip Flexors		
		Sartorius		
		Inward Rotation		
		Outward Rotation		
		Tensor Fasciae Latae		
		Hip Abductors		
		Hip Adductors		
		Quadriceps		
		Inner Hamstrings		
		Outer Hamstrings		
		Gastrocnemius		
		Anterior Tibial		
		Posterior Tibial		
		Peroneals		
		Extensor Longus Digitorum		
		Extensor Proprius Hallucis		
		Flexor Longus Digitorum		
		Short Toe Flexors		
		Flexor Longus Hallucis		
		Length		
		Thigh		
		Calf		

FIG. 7.—Leg examination sheet used in the After-Care Treatment Clinic of the Harvard Infantile Paralysis Commission.

knee, and pronounce that his muscles are gone if he is unable to do so. A knowledge of an easier position in which the weakened muscle can function may demonstrate a considerable amount of power remaining and may entirely change the prognosis as well as the treatment to be advised. On the other hand, it should be remembered that normal muscles not only produce movement through a certain arc of motion

FIG. 8.—Equinus—assumed with child sitting with weak dorsiflexors.

but are able to do so against a considerable degree of resistance and to hold the part in that position against a considerable amount of outside pressure. It is not safe to assert that a child has no weakness because he is able to move his arms and his legs about in bed. Partial paralysis is more common than total, and the presence of enough unparalyzed fibers in a muscle to straighten the knee in bed, or sitting up, does not prove that there are enough unaffected fibers in that muscle to hold the patient's weight in standing.

No. ....

Patient's Name ....

Cannot walk, walks unaided, with braces, crutches and corset.

Characteristic Gait ....

Scoliosis ....

	Left Leg	Contractions and Deformities	Right Leg	
		Hip		
		Knee		
		Ankle		
		Facial Orbit / Mouth		
		Anterior Neck		
		Posterior Neck		
		Back		
		Respiration		
		Quadratus Lumborum		
		Anterior Abdominals		
		Lateral Abdominals		
		Gluteus maximus		
		Hip Flexors		
		Sartorius		
		Inward Rotation		
		Outward Rotation		
		Tensor Fasciae Latae		
		Hip Abductors		
		Hip Adductors		
		Quadriceps		
		Inner Hamstrings		
		Outer Hamstrings		
		Gastrocnemius		
		Anterior Tibial		
		Posterior Tibial		
		Peroneals		
		Extensor Longus Digitorum		
		Extensor Proprius Hallucis		
		Flexor Longus Digitorum		
		Short Toe Flexors		
		Flexor Longus Hallucis		
		Length		
		Thigh		
		Calf		

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FIG. 8.—Equinus—assumed with child sitting with weak dorsiflexors.

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HARVARD INFANTILE PARALYSIS COMMISSION

No. ....

Patient's Name ....

Cannot walk, walks unaided, with braces, crutches and corset.

Characteristic Gait ....

Scoliosis ....

	Left Leg	Contractions and Deformities	Right Leg	
		Hip		
		Knee		
		Ankle		
		Facial Orbit		
		Facial Mouth		
		Anterior Neck		
		Posterior Neck		
		Back		
		Respiration		
		Quadratus Lumborum		
		Anterior Abdominals		
		Lateral Abdominals		
		Gluteus maximus		
		Hip Flexors		
		Sartorius		
		Inward Rotation		
		Outward Rotation		
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		Hip Adductors		
		Quadriceps		
		Inner Hamstrings		
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		Peroneals		
		Extensor Longus Digitorum		
		Extensor Proprius Hallucis		
		Flexor Longus Digitorum		
		Short Toe Flexors		
		Flexor Longus Hallucis		
		Length		
		Thigh		
		Calf		

FIG. 7.—Leg examination sheet used in the After-Care Treatment Clinic of the Harvard Infantile Paralysis Commission.

Equinus—If a shortened tendo achillis prevents the heel from touching the floor, so that the weight is borne wholly on the forefoot, the condition is called an equinus.

Valgus—If the adductors, the muscles which invert the foot, are the only weak muscles, the stronger abductor group, the peroneals, will pull the foot out into eversion (valgus). The patient will walk with the foot displaced outward and the internal malleolus will appear prominent. An equinus may also be present, in which case the deformity is called equinovalgus and the weight is borne on the toes with the foot displaced outward.

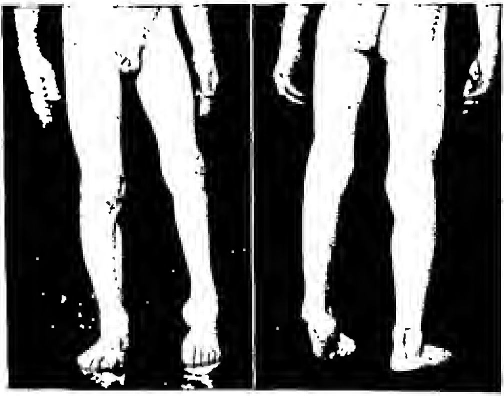

FIG. 10.—Equinovarus deformity due to weak dorsiflexors and peroneal group.

Varus—When the abductor group which everts the foot is weak, and the invertors are strong, the foot is turned in so that the weight is borne on the outer border of the foot. This deformity is called varus. It is frequently combined with an equinus.

Should all three of these groups be weakened, strength in the posterior calf group would still produce an equinus on account of the weakness of dorsiflexors, but the foot would not be displaced to either side if the invertors and the evertors were equally weak.

Calcaneus—Weakness of the gastrocnemius and soleus, when the opposing dorsiflexors are strong, results in a gait without spring. The weight is borne heavily on the heel, and the heel cord gradually becomes stretched out. This condition is known as calcaneus.

The details of making a complete muscle examination will be found in the later section on muscle training.

After the muscle examination, if the patient has been allowed to walk, it is very important to notice the weight-bearing position of his feet, knees and trunk as well as any fixed deformities which he may have acquired. The gait should also be analyzed very carefully.

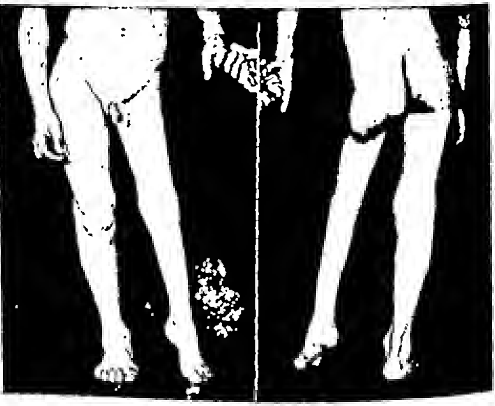

FIG. 9.—Equinus with tight heel cord

A form like the following may be of assistance:

FEET: (a) Do they turn out?
(b) Are they rolled in, the weight being borne on the outer border?
(c) Is there a foot drop—does he walk wholly on his toes?
(d) Does the weight come heavily on the heel without spring?

KNEES: (a) Are they locked back in hyperextension on weight bearing?
(b) Are they kept flexed at all times?

TRUNK: (a) Is the trunk carried forward and the hip permanently flexed?
(b) Is there a lateral curvature of the spine?
(c) Is the pelvis tilted down on one side?
(d) Does the patient stand with prominent abdomen and lordosis?

GAIT: Much can be learned from studying the gaits.

Toe drop—If the anterior dorsiflexor muscles of the lower leg are much weakened there will be a toe drop. The knee will be lifted high in taking a step in order to have the toes clear the floor.

Equinus—If a shortened tendo achillis prevents the heel from touching the floor, so that the weight is borne wholly on the forefoot, the condition is called an equinus.

Valgus—If the adductors, the muscles which invert the foot, are the only weak muscles, the stronger abductor group, the peroneals, will pull the foot out into eversion (valgus). The patient will walk with the foot displaced outward and the internal malleolus will appear prominent. An equinus may also be present, in which case the deformity is called equinovalgus and the weight is borne on the toes with the foot displaced outward.

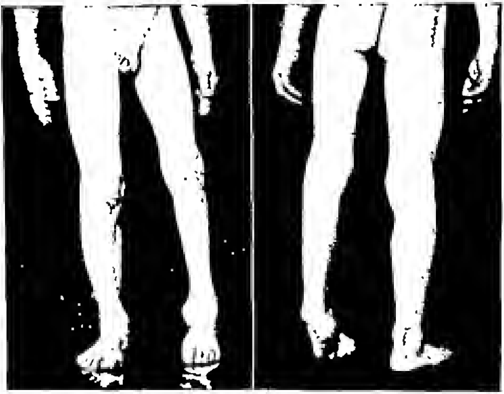

FIG. 10—Equinovarus deformity due to weak dorsiflexors and peroneal group.

Varus—When the abductor group which everts the foot is weak, and the invertors are strong, the foot is turned in so that the weight is borne on the outer border of the foot. This deformity is called varus. It is frequently combined with an equinus.

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Calcaneus—Weakness of the gastrocnemius and soleus, when the opposing dorsiflexors are strong, results in a gait without spring. The weight is borne heavily on the heel, and the heel cord gradually becomes stretched out. This condition is known as calcaneus.

Calcaneovarus—Greater strength in either the invertors or the evertors may cause a varus or a valgus in addition to the calcaneus.

Flail—A flail foot without fixed deformity results when there is severe paralysis of all the muscles of the lower leg, since no one group is strong enough to overbalance its opponent. In walking, a patient with a flail foot comes heavily on his heel and has a foot drop as well, when the foot is clear of the floor. A flail foot may be turned either out or in when weight-bearing, but is not fixed in any position.

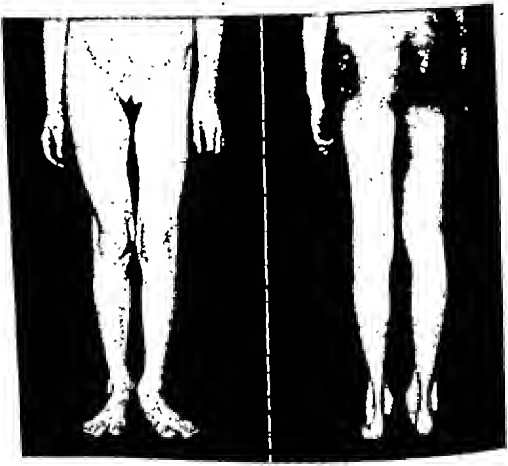

FIG. 11.—Valgus deformity due to weak adductor or tibial group.

Forefoot varus—A valgus foot or a flail foot may show varus of the forefoot if the plantar fascia is sufficiently contracted, without any change in the position of the os calcis.

Knee—The position of the knee in weight bearing should be noticed next, for hyperextension is very common. The function of the quadriceps extensor muscle is to keep the knee stiff in weight bearing. If this muscle is weak, there is constant danger of having the knee bend under the body weight, thus causing a fall. There are various ways in which a patient with a weak quadriceps may walk to lessen this danger. The common way is to keep the weight of the body in front of the center of the knee joint when standing on that leg. This may be accomplished

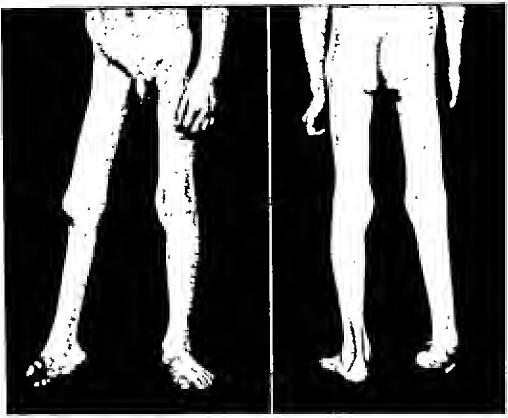

FIG. 12.—Varus deformity due to weak peroneal group.

FIG. 13.—Calcaneus deformity from weak gastrocnemius and unparalyzed dorsiflexors (Lovett.)

FIG. 14.—Hyperextended knees due to allowing weight bearing without support. (Lovett.)

by bending slightly forward and using the hand to press the thigh back each time the weight is taken on that leg. This locks the knee joint against flexion. Many patients accomplish this locking of the knee back in hyperextension without using the hand, by carrying the body ahead of the leg. This locking of the knee back in hyperextension is a severe strain on the posterior structures of the knee joint. If there is any considerable degree of weakness in the muscles which reënforce the knee joint posteriorly, either the hamstrings or the gastrocnemius, the knee is forced back into a greater degree of hyperextension than a normal joint will allow, and the joint capsule becomes permanently stretched. Extreme cases even present a backward bowleg. Once this deformity has developed, it is practically impossible to correct it even

FIG. 15.—Hand supporting thigh in standing with weak quadriceps.

though the quadriceps muscle may grow stronger, and the position is a potential cause of painful joint strain in later years, as well as a permanently awkward gait. A strong quadriceps may cause hyperextension of the knee in the presence of weak posterior muscles, but the mechanical locking of the knee necessitated by a weak quadriceps is a more frequent cause.

Another gait which is sometimes developed by the individual with a weak quadriceps is that of walking with the whole leg rotated out. The internal lateral ligaments of the knee take the strain in this case without locking the knee back. Efforts to train such a patient to walk with his foot and leg pointed forward will only result in increased falls, if his knee is not held by a brace.

A knee flexion contracture may cause walking with the knee bent.

The limps which are caused by weakness of the gluteal muscles are very awkward and noticeable. It is important to recognize them, since they are not usually improved by braces or by operations on the feet, and much disappointment will be avoided if this is explained to patients before undertaking measures which may improve the lower joints.

The function of the gluteal muscles in standing is to hold the pelvis in position over the leg which is taking the body weight at the moment. When the weight is taken on the left leg, for instance, the left gluteus maximus posteriorly tightens to prevent the pelvis from tipping forward so much that the erect position of the trunk will be lost. If this muscle is too weak to hold the pelvis back in place, the patient must either support himself with a crutch or a cane in front to prevent flexion from occurring at the hip, or else he must throw his trunk backward at the moment of stepping on the left leg; by so doing, the superincumbent weight of the trunk is brought behind the center of motion of the hip joint, and the danger of flexing the hip is prevented. This throwing of the body backward each time the patient steps on one of the legs is a definite sign of weakness of the gluteus maximus of that side. If the gluteus maximus of both sides is poor, the patient may walk without crutches, provided the knees are held in extension, by carrying his trunk posterior to his legs, the abdomen usually protruding. Efforts to teach him to stand with his weight forward only result in his sitting down backward unless crutches are substituted to hold him up.

Weakness of the left gluteus medius usually results in a throwing or bending of the trunk to the left side whenever the right foot is taken off the floor. When the support of the right leg is removed, the pelvis tends to drop down on the right side unless it is held by the left gluteus medius from doing so, or unless the trunk is tipped far enough over to the left to raise the right side of the pelvis. This tipping of the body to the weak side is the common abductor limp, and it is sometimes difficult to distinguish from a short-leg limp. Occasionally instead of tipping to the weak side, the opposite side of the pelvis is allowed to drop, in a limp similar to a mild Trendelenburg sign. Weak-

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ness of the abductors of both hips results in a waddle, tipping from side to side.

Weakness of both the gluteus medius and the gluteus maximus, hip abductor and extensor, on the same side, causes the body to be tipped diagonally back on the weak side.

Marked weakness of the hip flexors makes it difficult to move the leg straight forward, and this is usually overcome by a slight twist of the pelvis which brings the leg forward usually in outward rotation.

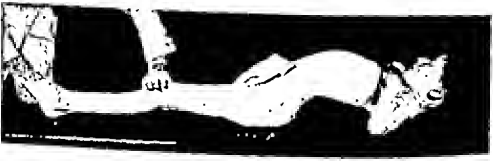

Fig. 16.—Lumbar lordosis due to hip contraction.

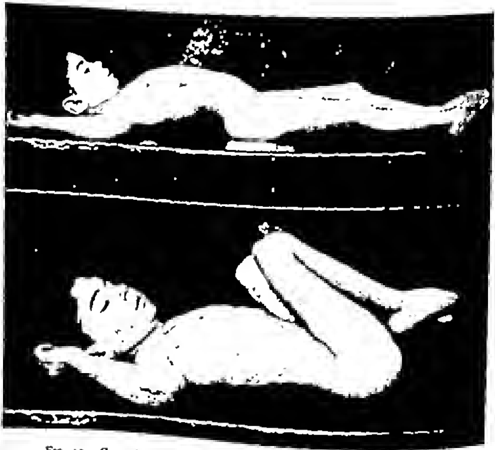

Fig. 17.—Case showing marked lumbar lordosis due to hip contraction.

Fig. 18.—Bulging abdomen when crying—right lateral abdominal weakness. (Lovett.)

Fig. 19.—Marked scoliosis with rotation from lack of adequate treatment.

ness of the abductors of both hips results in a waddle, tipping from side to side.

Weakness of both the gluteus medius and the gluteus maximus, hip abductor and extensor, on the same side, causes the body to be tipped diagonally back on the weak side.

Marked weakness of the hip flexors makes it difficult to move the leg straight forward, and this is usually overcome by a slight twist of the pelvis which brings the leg forward usually in outward rotation.

FIG. 16.—Lumbar lordosis due to hip contraction.

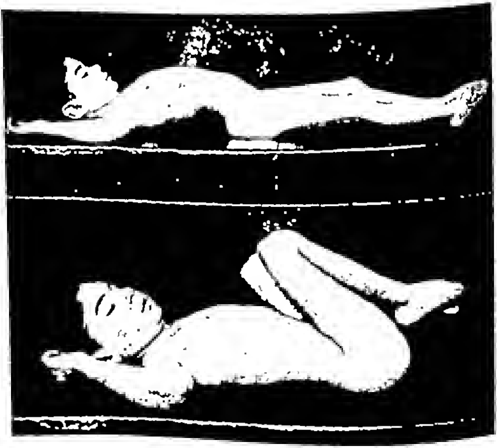

FIG. 17.—Case showing marked lumbar lordosis due to hip contraction.

FIG. 18.—Bulging abdomen when crying—right lateral abdominal weakness. (Lovett.)

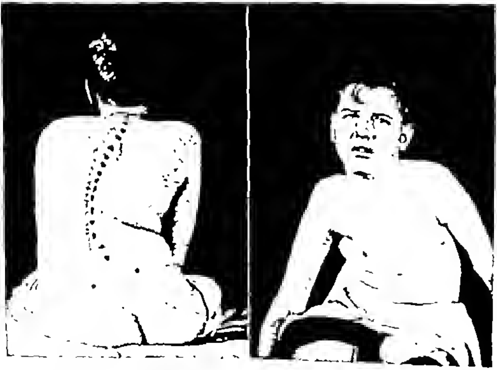

FIG. 19.—Marked scoliosis with rotation from lack of adequate treatment.

Shortening and abdominal paralysis also complicate the hip limps, and habit forms a very considerable element in the limp of a chronic patient.

If a child with weak hip extensors has been allowed to sit up a great deal with the hips flexed, it will be found that the hips are held per-

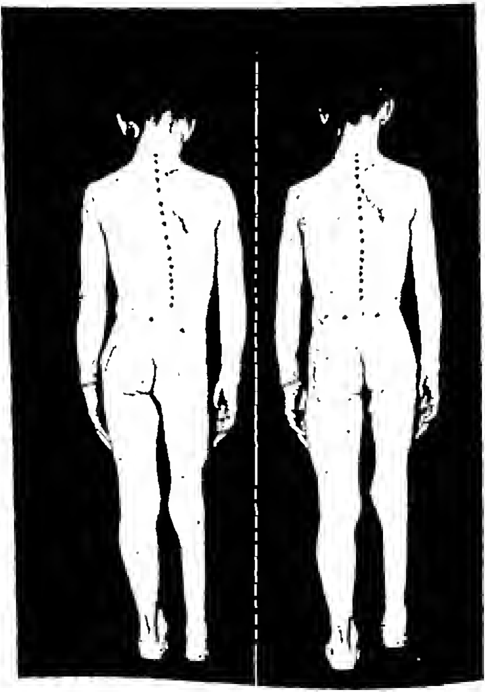

Fig. 10.—Right scoliosis due to short leg. Correction of same by equalizing length.

manently flexed when the time comes for the child to stand. This necessitates an increase in the normal physiologic curve of the lumbar spine in order to hold the body erect—in other words, a lordosis.

The patient with weak anterior abdominal muscles stands with a very prominent abdomen and often has the same tendency to arch the back.

Weakness in the lateral abdominal muscles usually results in standing or sitting with a list toward the stronger side, and a curvature in the spine. This is functional at first and very flexible, but if not properly supported may increase in severity very rapidly. Length of the legs, involvement of the shoulder, chest and back muscles, and efforts at maintaining equilibrium all play a part in determining the type of scoliosis which results.

Besides this detailed muscle examination and a recognition of any existing deformities or limp, the physician should inquire into other points which will be helpful in formulating an adequate plan of treatment. If the patient has been allowed to walk, questioning will often bring out the facts that he limps more when he is tired, or that he has trouble going up the stairs. The question of whether or not a slight case should go back to school may depend on these points, and the distance he will have to walk, or the number of stairs to be climbed. There may have been no apparent trouble with the arms during the acute stage, yet some weeks afterward it may be noticed that continued effort in writing or sewing causes undue fatigue and that the hand is used awkwardly. Inability to congh normally and clear the throat, difficulty in swallowing dry or solid food, and an unusually nasal voice are important points which may not be brought out in the muscle examination. A nervous irritability is frequently noticed in children who have been allowed to resume their normal activities too soon.

OUTLINE OF TREATMENT

The treatment to be advised at this time should still lay emphasis on the prevention of fatigue and of deformities. This is also the time above all others to concentrate on measures to reëducate the muscles, and to develop strength whenever response can be obtained.

All parents are anxious to get the child to sit up and be on his feet as quickly as possible. It is difficult to explain to them that sitting up and walking are the worst things that the child can be allowed to do, if his muscles are not strong enough to hold his body in the normal position. This is because faulty position puts the weakened muscles on the stretch, and they become fatigued from trying to work under a disadvantage. Stretching and fatigue make it more difficult for them to regain their strength, and their chance of recovery is definitely lessened. Habitual weight bearing in a deformed position results in a permanent deformity. Even though the muscles may gradnally become somewhat stronger, displaced bones and stretched ligaments do not

return to normal, and hyperextended knees, scoliosis and foot deformities do not disappear.

If the legs are not involved, there is no reason why a patient should not be allowed to walk when the sensitive stage is over, provided that the trunk is properly supported if it is weak and the arms are held in abduction if the deltoids are weak.

If there is even slight weakness of the legs, weight bearing and walking should be forbidden at this time.

It has been my routine to forbid walking and weight bearing in cases of slight leg involvement, until the muscles have regained their normal power. Even then one must be careful in guarding against muscle fatigue. Muscles which have been weakened by poliomyelitis, fatigue much more quickly than normal, even though their strength appears normal while undergoing manual tests.

If the legs are markedly involved, it has been my routine to prevent weight bearing for six or nine months if the muscles continue to show improvement under treatment, in order that the gain may not be checked by over-use. During this period, muscle recovery should be aided by daily massage to improve nutrition, and carefully carried out muscle training to strengthen the weakened muscles. If walking is not permitted, this treatment should be extended to include a normal leg in order to keep up its muscle tone. When the circulation is badly affected, it is well to employ some form of heat before the massage. Stimulation by electricity in any form at the present time has no place in the treatment of infantile paralysis, to my mind.

Cases with considerable involvement of the legs should continue to wear the posterior wire splints applied during the earlier stage. It is important, however, that these splints should be removed twice a day, and that as much motion as is possible without pain should be carried out in all the joints. Great care should be used in flexing the knee if the quadriceps has become tight from too long immobilization on the splint, as it is not uncommon to find definite trauma of the muscle when too much force is used.

Operative measures are not indicated at this time. It is not always necessary to wait two years before proceeding with operative measures, as the tradition has been handed down, but it is my belief that we should wait at least a year before doing transplantations or other operations in an attempt to reëstablish muscle balance. At the end of a year, a surgeon who has watched a case from the beginning will know fairly definitely how much more progress is likely to be made in regaining power under physical therapy treatment. In the case of marked contractures which have occurred from lack of early care, radical treatment should be instituted at any time before the end of a year if splints and manual stretching are found inadequate to overcome the deformities. No marked deformities

should ever occur in cases of poliomyelitis if efficient treatment has been advised and carried out from the start.

It is inexcusable to allow a case to go without receiving all possible benefits from muscle training and the prevention of deformity because the surgeon thinks that operative measures will be needed in the future. It is impossible to foretell at the start how much improvement can be obtained with treatment. Furthermore, the bony changes which take place when a deformity is neglected make a good end-result less likely. A patient is entitled to his chance of regaining as much power as possible under other forms of treatment before operative measures are considered.

The Fourth, or Chronic, Stage

The exact time when a case becomes chronic does not depend as much upon the number of months after the onset of the disease, as upon the time when its condition seems to be about stationary. The time of spontaneous improvement and of rapid gain under treatment is over, and it is obvious which muscles will always be badly weakened, although some further gain can usually be expected if treatment is continued. Deformities from lack of care, or from unequal balance, have become fixed, the affected limbs are definitely atrophied, and shortening has taken place.

It may be said that most of the spontaneous recovery will occur in three or four weeks. It may also be said that the most rapid gain under muscle training will be made in the first nine months to a year, as a general rule.

There are, however, many instances where a muscle does not show any particular gain for many months after the onset and later shows marked improvement. This is generally due to the fact that the muscle was allowed to be on the stretch, as in the case of a deltoid when the arm is allowed to hang by the side, or in other instances where a muscle is outpulled by its stronger antagonist. Faulty weight bearing may also put weakened muscles on the stretch.

It can be asserted that no weak muscle will come back if it is allowed to remain on the stretch, but it is difficult to foretell which of these stretched muscles may recover, if given a period of rest and reëducation with the strain removed. Certainly they are entitled to the chance, for there are numerous instances on record where poor muscles have regained good function after months of remaining at a standstill. One patient, G. S., received no treatment for a poor deltoid for ten months after the onset, at which time muscle training was started. A platform splint was applied one year after the onset. The poor deltoid showed no change during the first eight months of treatment, but in the next six months it improved to a "good" rating 2 3/12 years after the onset and 1 5/12 years after treatment was started.

FIG. 11.—Frame for instruction in walking for severe involvement of legs and trunk.

No physician will ever see a case of infantile paralysis for the first time without being asked what the outcome is going to be. It is a difficult question to answer at the first examination.

The parents can be told that some power will be regained in those muscles which are only weakened, but it is impossible to say just how much at this time. No prognosis can be made about the muscles which appear to be completely paralyzed, except that about 50 per cent of completely paralyzed muscles do regain some power, some of them even recovering normal strength if properly treated.

As to the general outlook for the patient, it is well to keep in mind that practically every patient will show some improvement under proper treatment, and that it is impossible to tell how much until it has been tried. It can always be said that a patient with good arms can be made to walk with the help of braces and crutches, even if both legs are useless, and many patients with badly weakened arms and trunk in addition to helpless legs can be taught to walk for short distances in apparatus. If serious deformities are prevented, there should not be more than a few patients out of any thousand cases of infantile paralysis who are too badly paralyzed to be taught to walk with apparatus.

A person without experience with large numbers of cases will do well to avoid the mistake of telling a patient that he can never walk again, for the probabilities are that the statement is not true and the effect is to discourage any effort toward recovery.

As has been said before, it can be told rather definitely at the end of a year what permanent inequality of muscle balance about a joint is going to exist. So at this time tendon transplantations to reëstablish an even balance of power about a joint may be considered for the improvement of function. Among the most common transplantations used in the foot are the following:

1. Setting the tendon of a peroneal or an anterior tibial muscle forward into the dorsum of the foot to strengthen dorsiflexion, in cases of equinus.

2. Setting the tendon of the peroneus longus in the inner side of the foot when weakness of the tibial muscles allows strong peroneals to hold the foot in valgus.

3. Setting the anterior tibial tendon to the outer side of the foot when there is weakness of the peroneals and a tendency to varus position on account of greater tibial strength.

4. Setting the peroneals, posterior tibial and sometimes the long toe flexors also directly into the os calcis to give them a stronger pull in plantar flexion when the gastrocnemius and soleus weakness has allowed a calcaneus to develop.

There are other combinations used, but no rules can be laid down, because all transplantation operations must depend on the relative strength of the different muscle groups affected by the operation.

Fig. 11.—Frame for instruction in walking for severe involvement of legs and trunk.

to improve the function of the shoulder are of little use if there is no power to use the hand or elbow.

Apparatus

Apparatus has two purposes in the treatment of infantile paralysis—to allow locomotion, and to prevent or correct deformity.

Provided that a child is making satisfactory gain under muscle training, it is our policy to keep him off his feet as long as possible

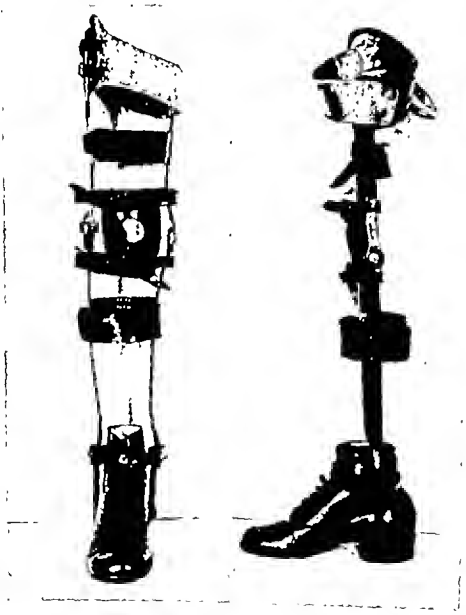

FIG. 11.—Long double calliper splint with drop catch at knee and flange at heel to prevent toe drop.

After transplantation the muscle must be reëducated to take on its new function and must be protected from fatigue, stretching and faulty weight bearing as carefully as any weak muscle.

The success of the operation depends largely upon a proper estimate of the strength of the opposing muscle groups. Muscles of less than fair powers do not, as a rule, function successfully in a new position. On the other hand, the transplantation of a strong muscle may so weaken the strength of its original group that overcorrection results in the production of a second deformity, the reverse of the original one.

Various transplantations may also be done at the knee and hip to improve function, provide greater stability for the joint, or lessen limps. The function of the thumb, hand and elbow may sometimes be improved by transplantations. Those done at the shoulder have not been particularly successful.

Besides tendon transplantations, bone stabilizations must be done in many cases. The object of a stabilization operation is to destroy motion between certain bones, so that they will be joined together in the correct position by bony union. This operation is required when fixed deformities have occurred on account of inefficient early treatment which has allowed bony changes to take place and the articulating relation between bones has been changed. Corrective operations may then have to be performed to replace the part in normal position as well as stabilization to hold it in place under weight bearing.

In these cases the after-treatment must be entirely different from that when transplantations alone have been done, because destroying mobility in certain directions also prevents the action of certain muscles. Very often the stronger muscles are utilized by transplanting them at the time of the stabilization so that they can assist in the action of the remaining joints.

Arthrodesis of the shoulder joint is an operation which destroys all motion in the joint and unites the humerus with the scapula. It may give the patient better use of his arm provided that the muscles controlling the scapula are strong and that he already has good function in his hand and the ability to flex his elbow in at least half supination.

The age at which a bony operation should be performed must be left to the judgment of the surgeon. Lack of firm union or disturbance of growth from injury to the epiphysial centers may follow if done at too early an age.

The question of bone lengthening should be discussed with any patient who has more than two inches of shortening in a leg.

The practical value of any operation should be carefully estimated before it is advised. The objects should be to correct deformity, to improve stability and lessen the amount of apparatus needed, or definitely to improve function when other means have failed. Operations

to improve the function of the shoulder are of little use if there is no power to use the hand or elbow.

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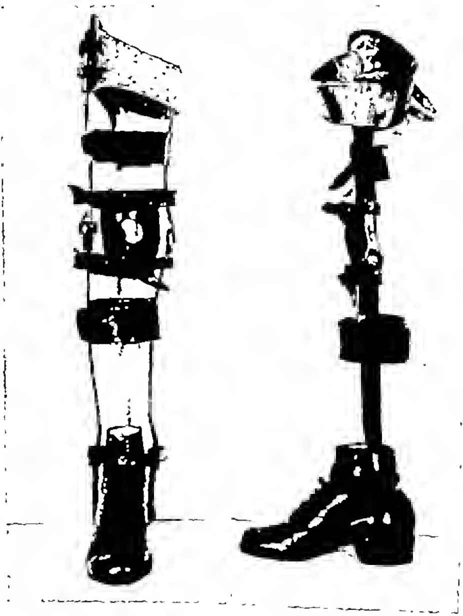

Fig. 22.—Long double calliper splint with drop catch at knee and flange at heel to prevent toe drop.

Fig. 13.—Double long callipers applied.

even though he may have fair power in his legs. It is not good policy to continue this restriction indefinitely on account of the general condition, however, and most patients with any severe involvement of the legs start walking before it is advisable for them to do so without support. Many other patients in clinic practice cannot be kept off their feet even though they would benefit more from the rest if it were possible.

In any case, after six or seven months, it is generally advisable to allow getting up on the feet for the effect on the general condition and the morale, even though the length of time daily may be restricted.

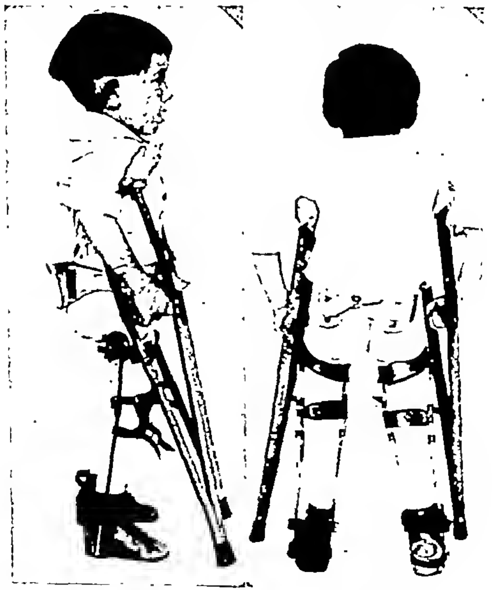

FIG. 24.—Sitting in braces. Position assumed where braces are too short.

Cases which have not been responding to treatment after six or seven months should also be started walking for the same reasons.

It is very important, however, that they should not be allowed to stand without supporting apparatus, if in so doing the knee, foot or leg is held in a deformed position. If any marked degree of unequal

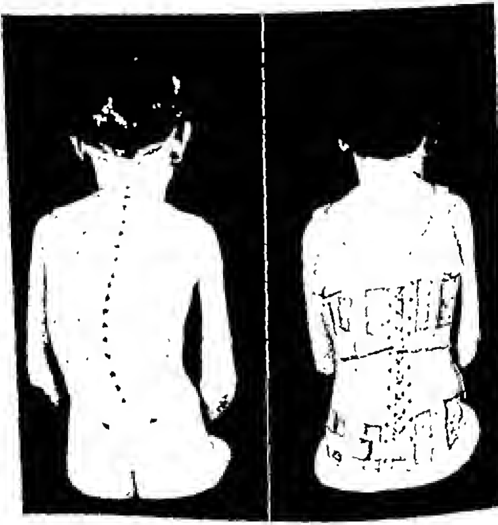

FIG. 25.—Early scoliosis due to weak abdominal muscles.

FIG. 25a.—Same case as Fig. 25, with corrective canvas corset.

muscle balance exists, weight bearing will cause the patient to stand in a deformed position, will stretch out the weakened muscles and cause overfatigue with resultant loss of power and, eventually, bony deformity.

Braces to prevent deformities of the foot may be of the caliper type or of the sole-plate type.

For calcaneus or equinus without lateral deformity of the foot, a simple caliper may be used with anterior or posterior flanges on the shoe socket to prevent dorsiflexion or foot drop as the case may be.

A sole-plate brace with straps or a leather anklet should be used to hold the foot in normal position if any lateral deformity exists. The ankle joint may be so constructed that it checks either dorsiflexion or foot drop according to the muscle balance.

FIG. 16.—Early scoliosis due to weak lateral abdominal muscles.

FIG. 16a.—Same case as Fig. 16, with corrective canvas corset with quadrilateral pad.

A high heel, either of cork inside the shoe or an elevation on the shoe itself, helps to take the strain off a weak gastrocnemius.

Tipping the shoe by an elevation of an eighth-inch to a quarter-inch on the inner border of the heel helps to take the strain off the tibial muscles and correct pronation; and, if necessary, a leather inner sole with a felt pad under the arch can also be used with a caliper brace.

An elevation on the outer border of the heel, or of the sole of the shoe, will help to correct a tendency to roll the foot in.

Cases with weak quadriceps usually hyperextend the knee and require a long brace reaching to the groin with straps at the knee to prevent its flexing when weight is put upon it, and also to prevent its being thrown back into hyperextension. A knee joint to allow greater

FIG. 27.—Case showing deviation of head to left due to right involvement of lateral neck muscles.

FIG. 27a.—Thomas collar for correction of neck deviation.

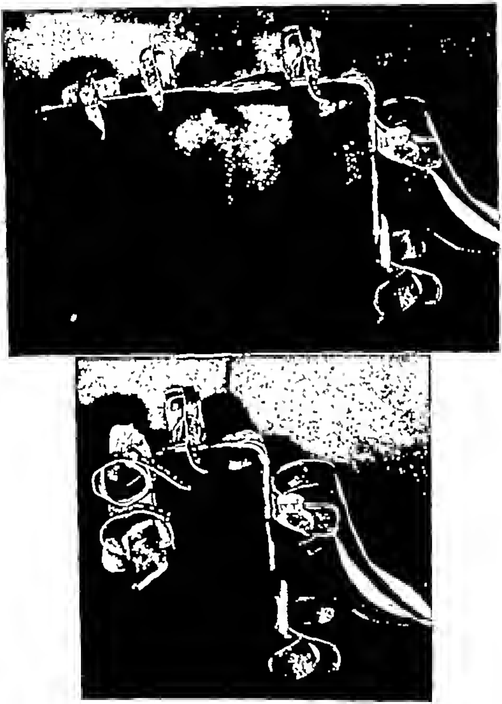

FIG. 18.—Arm abduction splint with elbow joint for use in deltoid paralysis.

comfort in sitting may be incorporated if the brace is built of flat metal, but should be locked in weight bearing.

The lower end of the brace may have a foot plate or be of the caliper type, as required.

Cases with weak abdominal muscles should have a stout, well-fitting corset made before they are allowed to sit up. Weak trunk muscles allow the body to tip to the side, with danger of causing a scoliosis. The corset is also an aid in getting the balance on starting to walk as well as an agent to prevent deformity.

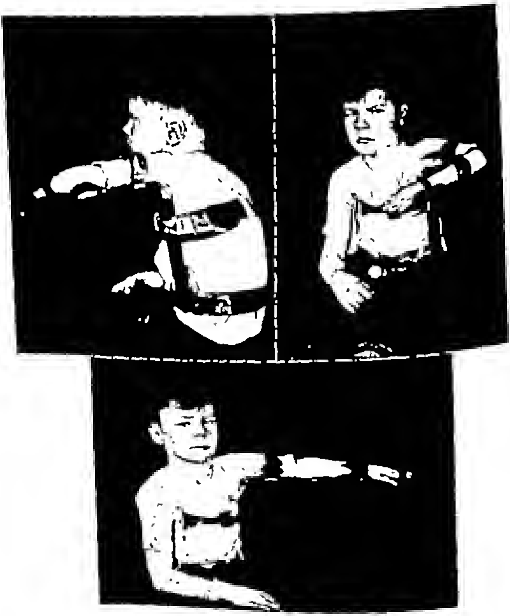

FIG. 19. Arm abduction splint applied with arm in flexion and extension.

In cases of severe weakness of the neck muscles, a collar should be worn to keep the head in the normal position.

Weakness of the deltoid muscle of the shoulder should be supported in abduction by a platform or aeroplane splint. If the arm is allowed to hang at the side, this muscle will become stretched from the drag of the arm. A sling is not as beneficial, because it favors the development of adduction contractures and does not hold the deltoid in the most

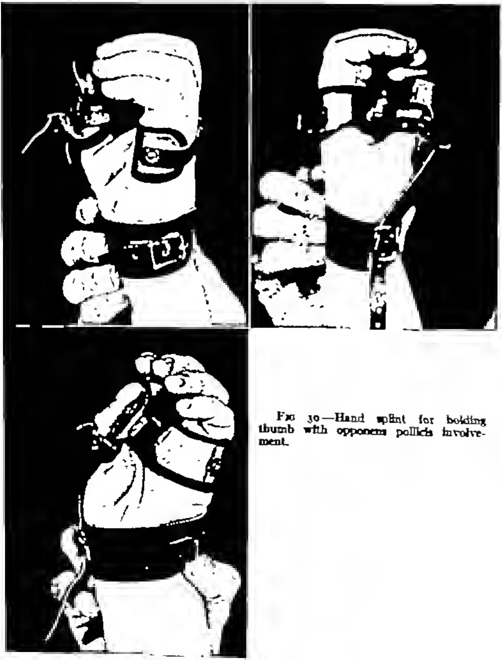

FIG 30—Hand splint for holding thumb with opponens pollicis involvement.

favorable position for recovery. The splint should be built with a joint at the elbow so that the forearm may be flexed if the biceps is weaker than the triceps, or held in extension if the triceps is weaker. Free motion may be allowed if the elbow and hand muscles are good. It is desirable to have the forearm supported in neutral position halfway between flexion and extension, rather than in full pronation.

A hand splint should be applied if there is lack of balance between the muscles at the wrist or in the hand.

For useful hand function, it is necessary to have the ability to grasp with the fingers flexing at all joints, with the wrist in some extension, and the thumb must be able to reach the finger-tips. In building a splint for a hand with a weak thumb, it is important to remember that the function of grasping things requires a thumb with its metacarpal bone nearly at a right angle to the palm of the hand in position for writing. The splint should be adapted to the muscle balance of the hand, and at the same time consideration should be given as to whether a palmar or cock-up splint will most benefit the wrist.

These patients should not be sent to a brace-maker for whatever type of stock brace he sees fit to apply. The doctor in charge of the case should decide what factors must be incorporated in the brace and must then supervise it personally to insure its doing the work desired.

Physical Therapy Treatment

Heat.—The application of some form of external heat should be included in the first part of the physical therapy treatment of any infantile paralysis patient whose muscles are extensively involved. Sluggish circulation and coldness of the affected extremities are commonly present, and it is well known that muscles cannot perform their best work when they are cold. It frequently happens that very weak muscles are unable to perform any movement whatever when they are cold, so it is evident that more benefit will be received from the muscle training if the part is thoroughly warmed first. The increase of the circulation through the affected part resulting from the local application of heat is valuable in keeping up the nutrition of the muscle fibers and in hastening the removal of waste products.

Heat may be applied in different ways. The most common and simplest means is by the use of a baker which consists of a reflector and either a special radiant light bulb or some form of heating element which is supposed to be rich in the infra-red wavelengths of the spectrum. There seems to be no particular advantage from using these infra-red bakers, since the radiant light bulbs give off as much heat as the skin will tolerate, and laboratory research seems to confirm the idea that visible light rays are more penetrating than infra-red. In choosing a radiant light baker, care should be taken that it is so constructed that the rays do not come to a focus at a burning point, as is sometimes the case in some of the cheaper single bulb types. Larger

FIG. 31.—Large baker to accommodate a number of children.

FIG. 32.—Baker with curtain drawn back.

bakers holding a number of bulbs will be found more efficient for cases with extensive involvement. The hanging type shown can be lowered to the desired height above a table, over which is spread an electric blanket, and the three or four small children placed inside the curtains are thoroughly warmed all over in ten or fifteen minutes.

The writer believes that there is no advantage to be gained by the use of medical diathermy as a means of producing heat in the treatment of infantile paralysis, and there are practical disadvantages in cases of extensive paralysis on account of the length of time required. The danger of burns is also greater with small children. For home use, hot blankets can be used, if no other form of heat is available.

Massage.—The physiologic effects of massage are similar to those of heat, in that both increase the blood supply and keep up the metabolism. In addition, massage is a form of passive exercise or manipulation of muscles which tends to prevent adhesions in muscles which are not normally active. Massage is fatiguing if given for long periods of time or with much force in an effort to warm up cold extremities. The preliminary use of heat will be found to shorten the time required for massage and to increase the circulation without fatiguing the muscles. It should always be borne in mind that massage in itself does not increase muscle power, and that massage alone does not constitute adequate treatment of weakened muscles.

The technic of giving massage is also important, for if poorly or improperly given, harm rather than benefit will result.

The pressure should be very light in order not to bruise the weakened muscle fibers, and the muscle should be raised from the bone rather than flattened down on it. Only enough pressure to quicken the blood circulation is needed, and no benefit occurs from using greater force. The direction of the pressure should be the same as that of the venous circulation and should never work against it. Stroking and kneading are the two manipulations most helpful for the muscles, and friction may be employed around contractures in addition to the definite stretching of the contracted tendons. There seems to be danger of harming atrophied paralyzed muscle fibers by the various forms of percussion intended to stimulate nerves and muscle fibers by sharp blows. The greatest care should be taken to prevent tiring or bruising the atonic muscle fibers by too heavy handling. Massage is a passive manipulation of the tissues, which should leave them in better condition for the voluntary efforts at movement—the so-called active exercises—which are necessary to develop strength.

The author personally prefers the Hoffa technic of massage in the treatment of infantile paralysis, because a point is made of taking the individual muscle group separately and following the direction of the muscle fibers with the stroke, which is always a continuous upward pressure from the distal to the proximal end.

Muscle Training *

By muscle training we mean the localized action of certain definite muscles or muscle groups—the attempt to exercise and develop certain muscles, without at the same time bringing into play other muscles whose action is, for some reason, undesirable. The object is a more localized action than that involved in the so-called corrective, or individual, gymnastics.

Muscle training is especially useful in the treatment of infantile paralysis. Some years ago, patients with weakened leg muscles were encouraged to be as active as possible, the theory being that exercise strengthened the muscles. Exercises were given to bring up the strength of the weakened leg, without much thought being given to what particular muscles were performing the exercises or what degree of weakness existed in individual muscles. The fact that fatigue increased the weakness in already weakened muscles was not considered, nor that a patient always tends to perform a movement by using the strong muscles rather than the weakened ones.

Some of the points in the physiology of muscles which have a practical bearing on muscle training are as follows:

Each muscle is made up of many muscle fibers. Action or contraction of a muscle makes the individual fibers shorter and thicker, and causes a chemical action with resultant waste products. These are normally removed by the circulation of the blood, and fresh blood is brought back. This is helped by the mechanical pumping action of the muscle fibers and joints on the blood vessels. If the circulation is not good, there is an accumulation of waste products with a resulting loss of muscle power. Exercises should be given in sufficiently slow rhythm, and time enough allowed between counts for recovery of the muscle.

Dr. Shepherd I. Franz, in his book, "Nervous and Mental Reeducation," states that "the complex nervous adjustments are made not only at the time a special exercise is taken, but also in the period of rest which follows one exercise and which precedes the next exercise." He also insists on the full arc of motion being made each time, in order to get the full mechanical effect of the joint action on the circulation.

The full arc of motion is also desirable in order to establish the habit reflex and obtain better coördination of the nerve centers through frequent repetition of a normal movement.

Passive movement is useless in restoring muscle power. There must be attempted voluntary movement until active movement is achieved.

A muscle can perform more work when the contraction is started from the stretched position than if the muscle is already partially

* The section on Muscle Training has been arranged by Miss Janet B. Merrill, Director of Physical Therapeutics at the Children's Hospital, Boston, to whom I am greatly indebted for her assistance.

contracted as movement is started. The muscles develop best when they are given all the work they can do without fatigue.

Beevor, in his lecture on "Muscular Movements and Their Representation in the Central Nervous System," states that a muscle may take part in two different movements—for instance, the biceps, which acts with the supinator brevis as a supinator, and also takes part with another group of muscles in flexion of the elbow. He states that it is possible that if one of these movements be lost owing to an organic lesion of the central nervous system and not the other movement, the biceps, which takes part in both movements, may be paralyzed for the one movement and not for the other.

Whenever free exercises are given in the effort to strengthen any individual muscle, other muscles are involuntarily contracted by the patient in the effort to localize the movement. Beevor explains synergic muscles as follows:

> When a muscle in passing over two or more joints has two or more different actions, then if only one of these actions be required, other muscles are brought into the movement whose actions are antagonistic to those of the muscles which are not required. The muscles which are brought into action to neutralize an action which is not required are called *synergic muscles*. Example: wrist flexors come into synergic action to prevent extension of wrist when extension of fingers alone is required. The *antagonists* are the finger flexors which relax during the movement of finger extension.

The general purposes of muscle training in poliomyelitis are:

1. To maintain and improve the circulation and nutrition.
2. To maintain muscle tone and prevent degeneration and atrophy of muscle fibers from disuse or from joint adhesions, in cases where the motor nerve supply is partially or temporarily interrupted.
3. To keep up tone in muscles whose nerve supply has been unimpaired during the period of recumbency or disuse.
4. To coördinate the remaining nerve centers where partial destruction of the centers controlling a part has occurred—reëducation by habit—while at the same time developing the fibers of the muscle which are still functioning normally, thus increasing the strength of the entire muscle.
5. To develop coördination and control.

A study of the cases following the epidemic in Vermont, in 1914, brought out the need for systematizing the examination of weakened muscles and analyzing the exercises given for their treatment. This work was done by Miss W. G. Wright, Dr. Robert W. Lovett's assistant. In 1916, the New York and Massachusetts victims of the epidemic were also treated under Dr. Lovett's supervision by methods learned from the experience in Vermont.

The routine of examining and grading muscle strength and the positions used in giving exercises to the different muscles according to the amount of power found upon examination will be described according to the system in use in the Harvard Infantile Paralysis Commission Clinic at the Children's Hospital, Boston. The method is based upon the work of Dr. Lovett and Miss Wright, as described in "The Treatment of Infantile Paralysis" by R. W. Lovett.

It seems almost unnecessary to state that some system of grading muscle power is necessary in order to follow the progress of the different muscles under treatment. Since we are working for the restoration of function, it seems most natural to grade the strength of muscles according to their functional ability. Then when we have clearly charted the relative functional strength of the different muscle groups, it is an easy matter to pick out the exercise positions best suited to the amount of power found. No one would attempt to strengthen a child with normal muscles by asking him to perform some stunt entirely beyond his strength, yet it is not uncommon to see infantile paralysis patients being urged to perform some exercise which is equally impossible for the partly paralyzed muscles. This may have very serious results for several reasons. In the cases of muscles so badly paralyzed that they can only start the movement, it often happens that after they have become fatigued by a number of efforts, they can no longer even start the movement, and this loss of their previous ability may persist for several days. There have been instances where returning power in the toes has been so damaged by over-use that it has been lost permanently.

In other cases we see too hard an exercise position chosen, which causes an attempt to reach the desired position by rotating the limb and substituting stronger muscles. This does not strengthen the muscles for which the exercise was intended.

Frequently, the relative strength of opposing muscle groups is disregarded, and we hear such remarks as, "No, he can't push it down much, but he pulls it up fine, so I let him do that, and then I put it down for him." In other words, an exercise intended for the extensors has become an active exercise for the stronger flexor group and only passive motion for the extensors. In this way the unequal balance of power about the point tends to become still more unequal as the stronger flexors increase in power under exercise and the extensors are neglected, and the danger of producing a deformity dne to unequal pull becomes steadily greater.

The general rules for muscle training are:

1. Avoid overfatiguing a muscle by overtreatment, by performing a movement rapidly or too many times.

2. Make each movement a voluntary active one performed by the patient in response to a stimulus. If no power is present, the patient should attempt the motion with concentration while the operator

carries out the motion "with help.". The patient should be instructed not to return the part to the starting position, but to relax after each effort and allow the operator to do the return movement passively.

3. See that the full arc of the motion is obtained each time. If necessary, help should be given in completing the arc, being careful to allow no pause at the point where the patient's strength gives out.

4. Localize the exercise by fixing the adjoining parts of the body so they will not take part in the movement. This is both to insure maximum concentration and effort in the desired action, and also to prevent substitution of other muscles. It is better to give one movement at a time than a combined movement of two parts at the same time; and if it is desired to give both flexion and extension exercises to the same joint, it is better to give them as two exercises with a rest between rather than have the patient attempt to exert his maximum effort during both parts of the exercises. Passive replacement of the part gives a chance for recovery before the next effort.

5. Give resistance to develop strength wherever possible. It should not be given until the muscle is able to complete the arc of motion unaided, and if given, it should always be a little less than that which would stop the movement or make it jerky, and should be graduated to leverage throughout.

6. Radiant heat with massage is desirable before the treatment is given, to start the circulation and make the muscle give a better response.

7. Ordinarily treatment is given once a day, six days a week. It is best to have each exercise done twice, at first, gradually increasing the number until it can be done ten times without fatigue. The whole treatment, including the massage, takes from twenty minutes to an hour, depending upon the extent of the paralysis. It is preferable whenever possible to have two short exercise periods a day rather than one long treatment.

8. If the splint or apparatus is removed, care should be taken not to allow the part to hang, and no stretch or strain should be allowed on the muscles which are being kept shortened in the splint.

9. Always have the part which is being exercised uncovered.

10. If possible, be alone with the patient in order to secure his entire concentration.

The foundation of muscle training is an exact knowledge of muscle anatomy, the origins, insertions and actions. This is necessary in order to determine which muscles are weakened, how they may be strengthened, and which muscles may be trained to take the place of the weakened ones.

The first preliminary to muscle training is an examination to determine the exact amount of power existing in the different muscle groups. For this, it is necessary to have a knowledge of the easiest positions for obtaining response and action from very weak muscles.

Our standard classification for grades of power is:

Gone—no contraction felt.
Trace—muscle can be felt to tighten, but can not produce movement.
Poor—produces movement with gravity eliminated, but cannot function against gravity.
Fair—can raise part against gravity.
Good—can raise part against outside resistance as well as against gravity.
Normal—can overcome a greater amount of resistance than a "good" muscle.

The second preliminary to muscle training is an intelligent decision regarding which muscle groups are to be strengthened. This is determined by:

(a) The presence of deformity or permanent contracture of the muscles. It is obviously unwise to strengthen muscles that are causing deformity or that are already contracted.

(b) The likelihood of causing deformity. In the presence of unequal balance of power about a joint, it is unwise to strengthen a muscle which already overbalances its opponent if this is likely to cause deformity.

(c) The relative importance of weakened muscles in regard to useful function of the limb, walking, correction of a limp, etc. The danger of fatigue from too many exercises should be borne in mind.

The third preliminary to muscle training is a knowledge of the type of exercise best suited to the amount of power remaining in the muscle to be developed.

There are three general types of exercises:

a. Those against gravity.
b. With gravity eliminated or neutralized.
c. With help of gravity.

There are three methods of giving an active or voluntary exercise:

a. With assistance.
b. Unaided or free.
c. Against resistance.

Type *a*, exercises against gravity, are suitable for fair and good muscles.

Type *b* exercises, with gravity eliminated or neutralized, are suitable for poor muscles and may be given in any one of the three ways named, i.e., with assistance, unaided, or against resistance, according to the strength of the muscle.

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3. See that the full arc of the motion is obtained each time. If necessary, help should be given in completing the arc, being careful to allow no pause at the point where the patient's strength gives out.

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6. Radiant heat with massage is desirable before the treatment is given, to start the circulation and make the muscle give a better response.

7. Ordinarily treatment is given once a day, six days a week. It is best to have each exercise done twice, at first, gradually increasing the number until it can be done ten times without fatigue. The whole treatment, including the massage, takes from twenty minutes to an hour; depending upon the extent of the paralysis. It is preferable whenever possible to have two short exercise periods a day rather than one long treatment.

8. If the splint or apparatus is removed, care should be taken not to allow the part to hang, and no stretch or strain should be allowed on the muscles which are being kept shortened in the splint.

9. Always have the part which is being exercised uncovered.

10. If possible, be alone with the patient in order to secure his entire concentration.

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The second preliminary to muscle training is an intelligent decision regarding which muscle groups are to be strengthened. This is determined by:

(a) The presence of deformity or permanent contracture of the muscles. It is obviously unwise to strengthen muscles that are causing deformity or that are already contracted.

(b) The likelihood of causing deformity. In the presence of unequal balance of power about a joint, it is unwise to strengthen a muscle which already overbalances its opponent if this is likely to cause deformity.

(c) The relative importance of weakened muscles in regard to useful function of the limb, walking, correction of a limp, etc. The danger of fatigue from too many exercises should be borne in mind.

The third preliminary to muscle training is a knowledge of the type of exercise best suited to the amount of power remaining in the muscle to be developed.

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a. Those against gravity.
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There are three methods of giving an active or voluntary exercise:

a. With assistance.
b. Unaided or free.
c. Against resistance.

Type *a*, exercises against gravity, are suitable for fair and good muscles.

Type *b* exercises, with gravity eliminated or neutralized, are suitable for poor muscles and may be given in any one of the three ways named, i.e., with assistance, unaided, or against resistance, according to the strength of the muscle.

Type *c*, exercises with the help of gravity, must be given against sufficient resistance to equal or support the weight of the limb; otherwise the part either will drop without the desired muscle action, or will be lowered by the opposite group.

In examining to establish a grade, it is first necessary to know whether the movement can be performed in a certain position, and next, whether the muscles can also overcome resistance while performing the movement. The determination of whether the strength is "good" or "normal" can best be told by having the patient hold the position while the examiner pulls until the muscles yield—the same principle used in the spring-balance muscle test as originally described by Lovett and Martin. Considerable experience with patients of different ages is necessary to make this differentiation between good and normal accurate, but the presence of some normal muscles is often an assistance in making the decision.

In giving exercises, it is not advisable to make a practice of having the patients hold the positions until their strength is overcome, as in examining, for this is fatiguing. It is better to have the muscles perform the movement against a graduated resistance, which should never be great enough to prevent the movement from being carried through smoothly.

In the following description, it is to be taken for granted that:

(a) Help is given to finish the movement whenever the muscles are unable to do so;
(b) The part is to be guided so that the movement is performed correctly;
(c) The instructor replaces the part in the starting position after each effort;
(d) Resistance is to be given whenever the muscles are strong enough to overcome it.

Since the positions used in examining muscles to determine their strength are often the same as the positions used for giving exercises to those muscles, the description of both will be given under the heading of the movement performed. The muscles which are in a position to help with the movement are listed under each heading.

Hip Extension.—Gluteus maximus. Gluteus medius and minimus. Hamstrings. Adductor magnus.

Examination.—

1. Prone lying.
   Fair muscles—should be able to raise the leg from the table with straight knee, keeping the leg in line with the body. Good or normal muscles—should be able to do this against downward pressure given by the examiner, and should hold the raised position against considerable pressure given on the thigh above the knee to lessen the participation of the hamstring muscles.

2. Affected side lying, with the knee drawn up to the chest. Poor muscles—should be able to perform at least part of the movement of pushing the thigh down and back into extension, and may be able to complete the movement even against some resistance, but cannot raise the leg against gravity in the prone position.

Exercises.—For good or fair muscles.
1. Prone lying, patient raises leg in air with straight knee.
2. Prone lying with the legs hanging over the edge of the table, patient raises leg to horizontal. (This position will lessen the amount of movement occurring in the lumbar spine.)
   For poor muscles.
3. Affected side lying with the underneath knee drawn up to the chest, patient pushes the thigh down and back into extension.
4. Patient lying on his back with the leg supported in the vertical position—pushes his leg down to the table against the resistance of the instructor's supporting hands. The knee should be kept straight throughout to eliminate effort at knee extension.
5. Opposite side lying with the affected leg supported in the instructor's hands—same exercise as in No. 3.

Hip Flexion.*—Psoas major and iliacus. Rectus femoris. Sartorius. Adductors longus and brevis. Pectineus. Gracilis. Obturator externus.

Examination.—
1. Sitting erect on edge of table, legs hanging.
   Fair muscles—should raise the knee to the chest.
   Good or normal muscles—should do this against a good deal of downward pressure. A tendency for the thigh to flex or hold in outward rotation signifies greater strength in the sartorius than in the other muscles concerned.
2. Affected side lying.
   Poor muscles—should be able to perform at least part of the movement of drawing the thigh up to the body.

Exercises.—For good or fair muscles.
1. Sitting erect on edge of table—patient raises the knee to the body, without tipping the body back or rotating the thigh.
2. Lying on the back—patient brings the knee up to the body.
   For poor muscles.
3. Affected side lying, patient draws the knee of the underneath leg up to the body.
4. Prone lying with legs off the end of the table—the leg is grasped at the ankle and raised to horizontal—patient then pulls the knee down and under the table, gravity helping.

* Hip flexion exercises should not be given if any hip flexion contraction exists.

Type *c*, exercises with the help of gravity, must be given against ıfficient resistance to equal or support the weight of the limb; otherise the part either will drop without the desired muscle action, or will e lowered by the opposite group.

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(b) The part is to be guided so that the movement is performed correctly;

(c) The instructor replaces the part in the starting position after each effort;

(d) Resistance is to be given whenever the muscles are strong enough to overcome it.

Since the positions used in examining muscles to determine their strength are often the same as the positions used for giving exercises to those muscles, the description of both will be given under the heading of the movement performed. The muscles which are in a position to help with the movement are listed under each heading.

Hip Extension.—Gluteus maximus. Gluteus medius and minimus. Hamstrings. Adductor magnus.

EXAMINATION.—

1. Prone lying.

FAIR muscles—should be able to raise the leg from the table with straight knee, keeping the leg in line with the body. GOOD or NORMAL muscles—should be able to do this against downward pressure given by the examiner, and should hold the raised position against considerable pressure given on the thigh above the knee to lessen the participation of the hamstring muscles.

2. Affected side lying, with the knee drawn up to the chest. POOR muscles—should be able to perform at least part of the movement of pushing the thigh down and back into extension, and may be able to complete the movement even against some resistance, but cannot raise the leg against gravity in the prone position.

EXERCISES.—For GOOD or FAIR muscles.
1. Prone lying, patient raises leg in air with straight knee.
2. Prone lying with the legs hanging over the edge of the table, patient raises leg to horizontal. (This position will lessen the amount of movement occurring in the lumbar spine.)
   For POOR muscles.
3. Affected side lying with the underneath knee drawn up to the chest, patient pushes the thigh down and back into extension.
4. Patient lying on his back with the leg supported in the vertical position—pushes his leg down to the table against the resistance of the instructor's supporting hands. The knee should be kept straight throughout to eliminate effort at knee extension.
5. Opposite side lying with the affected leg supported in the instructor's hands—same exercise as in No. 3.

Hip Flexion.*—Psoas major and iliacus. Rectus femoris. Sartorius. Adductors longus and brevis. Pectineus. Gracilis. Obturator externus.

EXAMINATION.—
1. Sitting erect on edge of table, legs hanging.
   FAIR muscles—should raise the knee to the chest.
   GOOD or NORMAL muscles—should do this against a good deal of downward pressure. A tendency for the thigh to flex or hold in outward rotation signifies greater strength in the sartorius than in the other muscles concerned.
2. Affected side lying.
   POOR muscles—should be able to perform at least part of the movement of drawing the thigh up to the body.

EXERCISES.—For GOOD or FAIR muscles.
1. Sitting erect on edge of table—patient raises the knee to the body, without tipping the body back or rotating the thigh.
2. Lying on the back—patient brings the knee up to the body.
   For POOR muscles.
3. Affected side lying, patient draws the knee of the underneath leg up to the body.
4. Prone lying with legs off the end of the table—the leg is grasped at the ankle and raised to horizontal—patient then pulls the knee down and under the table, gravity helping.

* Hip flexion exercises should not be given if any hip flexion contraction exists.

5. Opposite side lying, with the affected leg supported in the instructor's hands—same exercise as in No. 3.

duction.—Gluteus medius and minimus. Gluteus maximus, upper fibers. Sartorius, and the small outward rotators of the hip, when the hip is flexed. Tensor fasciae femoris.

EXAMINATION.—

1. Lying on the opposite side.
   FAIR abductors should raise the upper leg in the air through the normal range of abduction.

FIG. 33.—Guiding hip abduction.

GOOD muscles should do so against downward pressure.
The strength of the tensor fasciae femoris is obtained better if the leg is raised in some flexion, while the action is more purely gluteal if the leg is kept in line with the body, and the knee straight.

It will be found that the tensor fasciae femoris can hold the leg with good power at about a horizontal level but is not able to finish the full range of abduction without fair power in the gluteus medius and minimus.

2. Lying on the back with the pelvis held.
   POOR muscles should be able to move the leg out to the side.

EXERCISES.—For GOOD or FAIR muscles.

1. Lying on the opposite side of the body, patient raises the upper leg in abduction.

   For POOR muscles.
2. Lying on the back, pelvis held, patient moves the leg out to the side, without rotation of the leg or flexion of the knee. Powder may be used to lessen friction, or the leg may be supported in the instructor's hands.
3. Prone lying—same exercise. This position requires more effort from the gluteal muscles and less from the flexor abductors.
4. Sitting—abduction of the thigh, particularly suitable for the flexor abductors.

   Flexion abduction exercises should not be given if any contraction of the tensor fasciae femoris exists.

TEST FOR CONTRACTURE OF TENSOR FASCIAE FEMORIS

Patient prone lying, with legs hanging over the table edge. Examiner holds pelvis down with one hand and, with the other hand under the knee, grasps leg and raises the thigh in line with the body, until horizontal, and then adducts it. This position brings out a beginning contracture more clearly than when movement in the lumbar spine is allowed to take place.

Adduction.—Adductor longus. Adductor magnus. Adductor brevis. Gracilis. Quadratus femoris. Lower fibers of gluteus maximus. Pectineus.

EXAMINATION.—

1. Lying on affected side, with other leg held up by examiner in position of abduction.

   FAIR muscles should raise the under leg several inches from the table.
2. Lying on the back, with the leg out in abduction.

   POOR muscles should draw the leg in toward the other leg.

   On account of frequent substitution of the internal hamstrings, the thigh should not be allowed to rotate outward, and the adductor tendon should be felt.

EXERCISES.—For GOOD or FAIR muscles.

1. Lying on the affected side, patient raises the affected leg from the table, knee straight.

   For POOR muscles.
2. Lying on the back, with the leg out in abduction, patient draws the leg in to the other leg, keeping the foot pointing straight in the air.
3. Lying on the opposite side, with the affected leg supported in the air in abduction, patient pulls the leg down, gravity assisting.

5. Opposite side lying, with the affected leg supported in the instructor's hands—same exercise as in No. 3.

Abduction.—Gluteus medius and minimus. Gluteus maximus, upper fibers. Sartorius, and the small outward rotators of the hip, when the hip is flexed. Tensor fasciae femoris.

EXAMINATION.—

1. Lying on the opposite side.
FAIR abductors should raise the upper leg in the air through the normal range of abduction.

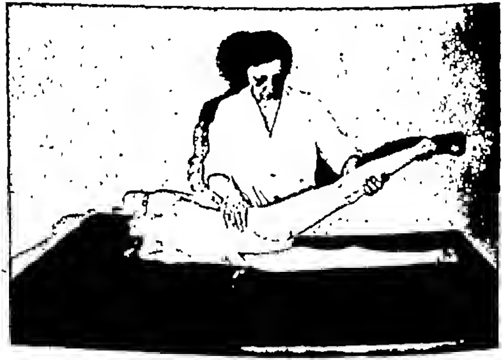

FIG 33.—Guiding hip abduction.

GOOD muscles should do so against downward pressure.
The strength of the tensor fasciae femoris is obtained better if the leg is raised in some flexion, while the action is more purely *gluteal* if the leg is kept in line with the body, and the *knee* straight.

It will be found that the tensor fasciae femoris can hold the leg with good power at about a horizontal level but is not able to finish the full range of abduction without fair power in the gluteus medius and minimus.

2. Lying on the back with the pelvis held.
POOR muscles should be able to move the leg out to the side.

EXERCISES.—For GOOD or FAIR muscles.

1. Lying on the opposite side of the body, patient raises the upper leg in abduction.

   For POOR muscles.

2. Lying on the back, pelvis held, patient moves the leg out to the side, without rotation of the leg or flexion of the knee. Powder may be used to lessen friction, or the leg may be supported in the instructor's hands.
3. Prone lying—same exercise. This position requires more effort from the gluteal muscles and less from the flexor abductors.
4. Sitting—abduction of the thigh, particularly suitable for the flexor abductors.

   Flexion abduction exercises should not be given if any contraction of the tensor fasciae femoris exists.

TEST FOR CONTRACTURE OF TENSOR FASCIAE FEMORIS

Patient prone lying, with legs hanging over the table edge. Examiner holds pelvis down with one hand and, with the other hand under the knee, grasps leg and raises the thigh in line with the body, until horizontal, and then adducts it. This position brings out a beginning contracture more clearly than when movement in the lumbar spine is allowed to take place.

Adduction.—Adductor longus. Adductor magnus. Adductor brevis. Gracilis. Quadratus femoris. Lower fibers of gluteus maximus. Pectineus.

EXAMINATION.—

1. Lying on affected side, with other leg held up by examiner in position of abduction.

   FAIR muscles should raise the under leg several inches from the table.

2. Lying on the back, with the leg out in abduction.

   POOR muscles should draw the leg in toward the other leg.

   On account of frequent substitution of the internal hamstrings, the thigh should not be allowed to rotate outward, and the adductor tendon should be felt.

EXERCISES. For GOOD or FAIR muscles.

1. Lying on the affected side, patient raises the affected leg from the table, knee straight.

   For POOR muscles.

2. Lying on the back, with the leg out in abduction, patient draws the leg in to the other leg, keeping the foot pointing straight in the air.
3. Lying on the opposite side, with the affected leg supported in the air in abduction, patient pulls the leg down, gravity assisting.

4. Sitting on the edge of the table with the thigh in abduction, patient draws the thigh into the other leg.

INTERNAL AND EXTERNAL ROTATION OF THE THIGH

There is considerable divergence of opinion among authorities as to the muscles taking part in these movements, and examination is generally unsatisfactory. This is because the small muscles, such as the gemelli, cannot be seen or felt to function, and the other muscles can be more accurately tested in their other functions. Furthermore, it is not uncommon to find a patient walking with his leg in external rotation, in spite of the fact that his strength in internal rotation is apparently greater when he is off his feet. Since the small hip-outward rotators are generally supposed to abduct the thigh, when the hip is flexed, and to rotate it out, when the thigh is extended, some idea of their strength can be obtained by trying outward rotation in both positions of the thigh.

External Rotation.—

Sartorius Pectineus	Posterior fibers of gluteus medius and minimus
Adductor longus Adductor brevis	Lower fibers of gluteus maximus
Adductor magnus Biceps	Iliopsoas
Pyriformis Gemelli Quadratus femoris Obturator externus and internus	when thigh is in extension

EXAMINATION AND EXERCISE.—

1. Sitting with lower legs hanging.
   FAIR muscles should raise the lower leg across in front of the other leg while rotating the thigh out.
2. Lying on the back.
   POOR muscles should roll the whole leg outward.

Internal Rotation.—Tensor fasciae femoris. Anterior fibers of gluteus medius and minimus.

EXAMINATION AND EXERCISE.—

1. Sitting with knees flexed, lower legs hanging, patient should raise lower leg to the side away from the other leg while keeping the knees together.
2. Lying on the back, patient should roll the whole leg in from the hip.

EXTENSION

Knee.—Quadriceps.

EXAMINATION.—

1. For normal strength in a child. Squatting in deep knee-bend position with all the weight on one leg, patient comes to the erect position by straightening the bent knee. Patient's other leg and hands may be steadied by the examiner. This test is not suitable for adults or markedly overweight children, and gastrocnemius and gluteus maximus strength are also required in order to attain the erect position.
2. Sitting on edge of table, legs hanging.
   FAIR muscles should raise the lower leg to horizontal, without thigh rotation.
   GOOD muscles should do this against downward pressure. It is difficult to decide whether this muscle is normal, because sufficient force may be exerted against older children to raise the patient's body from the table, without causing the knee to bend, and yet a history may be given of weakness shown in normal or athletic activities.
3. Affected side lying, with the thigh held firmly in slight extension by the examiner, knee flexed.
   POOR muscles should be able to perform at least part of the movement of straightening the knee, and may be able to perform it against some resistance, but cannot extend it in the sitting position against gravity.

EXERCISES.—For GOOD or FAIR muscles.

1. Sitting on edge of table, patient raises lower leg to horizontal.
2. Lying on back with lower leg hanging over edge of table, patient raises lower leg to horizontal. (The additional tension placed on the rectus femoris in this position makes the exercise slightly easier than in the sitting position.)
3. Lying on back, raising the leg in the air with straight knee is more properly a hip flexion exercise.
   For POOR muscles.
4. Affected side lying, same position as in examination No. 3. The exercise is made easier by holding the thigh firmly back in extension, or somewhat harder if the thigh is held in some flexion, during the movement of knee extension. The greater tension of the rectus femoris in the first position makes it easier to start the movement than when the muscle is relaxed by hip flexion.
5. Lying on the back, "setting" the muscle by attempting to pull on the patella without moving the leg.
6. Prone lying, with the knee flexed and lower leg vertical, patient extends the knee against resistance given in front of the ankle.

4. Sitting on the edge of the table with the thigh in abduction, patient draws the thigh into the other leg.

INTERNAL AND EXTERNAL ROTATION OF THE THIGH

There is considerable divergence of opinion among authorities as to the muscles taking part in these movements, and examination is generally unsatisfactory. This is because the small muscles, such as the gemelli, cannot be seen or felt to function, and the other muscles can be more accurately tested in their other functions. Furthermore, it is not uncommon to find a patient walking with his leg in external rotation, in spite of the fact that his strength in internal rotation is apparently greater when he is off his feet. Since the small hip-outward rotators are generally supposed to abduct the thigh, when the hip is flexed, and to rotate it out, when the thigh is extended, some idea of their strength can be obtained by trying outward rotation in both positions of the thigh.

External Rotation.—

Sartorius	Posterior fibers of gluteus medius and minimus
Pectineus	
Adductor longus	Lower fibers of gluteus maximus
Adductor brevis	
Adductor magnus	Iliopsoas
Biceps	
Pyriformis	when thigh is in extension
Gemelli	when thigh is in extension
Quadratus femoris	when thigh is in extension
Obturator externus and internus	when thigh is in extension

EXAMINATION AND EXERCISE.—

1. Sitting with lower legs hanging.
   FAIR muscles should raise the lower leg across in front of the other leg while rotating the thigh out.
2. Lying on the back.
   POOR muscles should roll the whole leg outward.

Internal Rotation.—Tensor fasciae femoris. Anterior fibers of gluteus medius and minimus.

EXAMINATION AND EXERCISE.—

1. Sitting with knees flexed, lower legs hanging, patient should raise lower leg to the side away from the other leg while keeping the knees together.
2. Lying on the back, patient should roll the whole leg in from the hip.

For POOR muscles.

2. Affected side lying, thigh of lower leg held firmly, patient bends the knee. If the thigh is held forward in flexion, the exercise will be easier than if the thigh is held in line with the body.
3. Lying on back, with the leg held vertical by the instructor, patient bends the knee, pulling the lower leg down against the resistance of the instructor's supporting hand—thigh remains vertical.
4. Sitting on the edge of the table with the lower leg supported at horizontal, patient bends the knee, pulling the leg down under the table.

Plantar Flexion (bending ankle so that toes point down).—Gastrocnemius and soleus. Peroneus longus and brevis. Flexor digitorum longus. Plantaris. Tibialis posticus. Flexor hallucis longus.

EXAMINATION.—

1. Standing on one foot.
   NORMAL muscles should raise the body weight on the tiptoes at least ten times.
   GOOD muscles should enable the patient to walk on tiptoes or rise on tiptoes less than ten times.
2. Prone lying, foot off the table edge.
   FAIR muscles should point the foot up, against considerable downward pressure on the ball of the foot.
3. Affected side lying, knee straight.
   POOR muscles should push the foot down. It is important to watch for action of the tendo achillis, since this is the tendon of the strongest plantar flexor, the gastrocnemius. Of the other plantar flexors, the long toe flexors will act first on the toes before moving the ankle, and the peroneals and posterior tibial act first on the forefoot. Gastrocnemius strength, shown by the pull of the tendo achillis on the heel, is necessary for good plantar-flexion function.

EXERCISES.—For GOOD muscles.

1. Standing on one foot, rise on tiptoes or walk on tiptoes.
   For FAIR muscles.
2. Lying face down, with the knee flexed and the lower leg vertical, or with the knee straight and the foot over the edge of the table, patient plantar-flexes ankle against pressure on the ball of the foot.
   For POOR muscles.
3. Patient sitting, points the foot down against resistance.
4. Affected side lying, patient points the foot down, being careful to use the tendo achillis.

Thigh should be held down firmly by the instructor. This exercise may be made harder for stronger muscles by increasing the resistance and by starting the movement with the knee completely flexed so that gravity must be overcome at first.

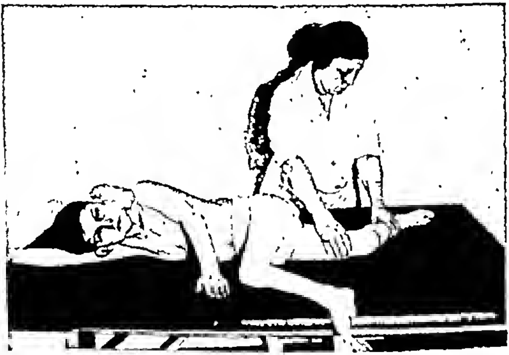

FIG. 34.—Exercise for "poor" knee extensor—thigh fixed.

FLEXION

Knee.—Biceps. Popliteus. Sartorius. Gracilis. Semimembranosus. Semitendinosus. Gastrocnemius. Plantaris.

EXAMINATION.—

1. Prone lying.
   FAIR muscles should raise the lower leg to vertical.
   GOOD OF NORMAL muscles should do this against downward pressure on the lower leg. The thigh should be held down firmly throughout movement.
2. POOR muscles, affected side lying, with the thigh held firmly in front of the body, hip flexed to give greater tension on the hamstring muscles. Examiner should feel the tendons of both the internal and external hamstring muscles during flexion of the knee.

EXERCISES.—For GOOD or FAIR muscles.

1. Prone lying, patient bends the knee, raising the lower leg to vertical.

For POOR muscles.

3. Lying on the back, patient turns the foot in.
4. Prone lying, with the foot off the end of the table, patient turns the foot in.

   Deformity which results from weakness of this group—valgus (foot is displaced outward).

   Exercise to be avoided—eversion.

EVERSION

Peroneus longus, brevis, tertius   Extensor digitorum longus

EXAMINATION AND EXERCISES.—

1. Sitting or lying, patient turns the foot out.

   The strength of the movement and the amount of resistance overcome determine the grading.

   Deformity which results from weakness of this group—varus (foot is turned in).

   Exercise to be avoided—inversion.

Since these muscles take part in more than one movement of the foot or toes, and it is not uncommon for one muscle to be weaker than the others of its group, it is customary to estimate their strength separately, as well as testing the group as a whole.

The tibialis anterior is a dorsal flexor of the foot, as well as an invertor. Its tendon is the innermost of the three tendons which can be seen and felt, across the front of the ankle joint in a normal foot. In carrying out the examination positions and exercises just described, the larger part of the movement will be performed by the tibialis anterior if the foot is pulled up at the same time that it is being turned in.

The tendon of the tibialis posterior can be felt just above and behind the internal malleolus, and it can be felt to contract more strongly if the foot is pointed down as it is being turned in.

The extensor digitorum longus extends the four lesser toes, but its strength is best obtained while carrying out the movement of dorsiflexion, with the foot in slight abduction.

The extensor hallucis longus extends the great toe, but its strength is best obtained in dorsiflexion. Its tendon may sometimes be confused with that of the tibialis anterior, unless it is traced to its insertion on the toe.

The great toe and the next three toes can sometimes be extended, in the absence of the long toe extensors, by the extensor digitorum brevis. Inability to identify motion of the tendons of the long extensors where they cross the ankle joint, accompanied by loss of dorsiflexion power, will justify the examiner in attributing extension power in these four toes to the extensor digitorum brevis or to the interossei.

Deformity which results from weakness of this group—calcaneus —the weight coming heavily on the heel in walking.
Exercise to be avoided—dorsiflexion.

Dorsiflexion (bending the ankle up).—Tibialis anterior. Extensor hallucis longus. Extensor digitorum longus. Peroneus tertius.

EXAMINATION.—

1. Sitting with lower leg hanging over the edge of the table.
   FAIR muscles should bend the ankle up to a right angle, if not prevented by a short heel cord.
   GOOD muscles should do this against downward pressure on the top of the foot. (Even strength in the four muscles will result in the foot being brought up straight, but in case of unequal power, one side of the foot may be raised higher than the other or held more firmly in that position when resistance is given.)
2. Lying on the affected side.
   POOR muscles should bend the ankle up.

EXERCISES.—For FAIR and GOOD muscles.

1. Sitting on the edge of the table, patient bends the ankle up in dorsiflexion. Instructor should guide the foot straight, if it tends to turn out or in during the movement.
   For POOR muscles.
2. Affected side lying, patient bends the ankle up in dorsiflexion.
3. Back lying, the same exercise.
4. Prone lying, with the lower leg held vertical and the foot pointed in the air, patient bends the ankle in dorsiflexion, pulling the toes down toward the table.
   Deformity resulting from weakness of this group—foot drop.
   Exercise to be avoided—plantar flexion.

INVERSION

Tibialis anterior	Tibialis posterior
Extensor hallucis longus	Flexor hallucis longus

EXAMINATION.—For FAIR and GOOD muscles.
(The lower leg should be held to prevent rotation.)

1. Lying on affected side, patient lifts the forefoot from the table while keeping the heel on the table.
   For POOR muscles.
2. Sitting on the edge of the table, patient turns the foot in.

EXERCISES.—For FAIR or GOOD muscles.

1. Lying on affected side, patient lifts the forefoot from the table.
2. Sitting on the edge of the table, patient turns the foot in against resistance.

For POOR muscles.

3. Lying on the back, patient turns the foot in.
4. Prone lying, with the foot off the end of the table, patient turns the foot in.

   Deformity which results from weakness of this group—valgus (foot is displaced outward).

   Exercise to be avoided—eversion.

EVERSION

Peroneus longus, brevis, tertius   Extensor digitorum longus

EXAMINATION AND EXERCISES.—

1. Sitting or lying, patient turns the foot out.

   The strength of the movement and the amount of resistance overcome determine the grading.

   Deformity which results from weakness of this group—varus (foot is turned in).

   Exercise to be avoided—inversion.

Since these muscles take part in more than one movement of the foot or toes, and it is not uncommon for one muscle to be weaker than the others of its group, it is customary to estimate their strength separately, as well as testing the group as a whole.

The tibialis anterior is a dorsal flexor of the foot, as well as an invertor. Its tendon is the innermost of the three tendons which can be seen and felt, across the front of the ankle joint in a normal foot. In carrying out the examination positions and exercises just described, the larger part of the movement will be performed by the tibialis anterior if the foot is pulled up at the same time that it is being turned in.

The tendon of the tibialis posterior can be felt just above and behind the internal malleolus, and it can be felt to contract more strongly if the foot is pointed down as it is being turned in.

The extensor digitorum longus extends the four lesser toes, but its strength is best obtained while carrying out the movement of dorsiflexion, with the foot in slight abduction.

The extensor hallucis longus extends the great toe, but its strength is best obtained in dorsiflexion. Its tendon may sometimes be confused with that of the tibialis anterior, unless it is traced to its insertion on the toe.

The great toe and the next three toes can sometimes be extended, in the absence of the long toe extensors, by the extensor digitorum brevis. Inability to identify motion of the tendons of the long extensors where they cross the ankle joint, accompanied by loss of dorsiflexion power, will justify the examiner in attributing extension power in these four toes to the extensor digitorum brevis or to the interossei.

Deformity which results from weakness of this group—calcaneus —the weight coming heavily on the heel in walking.
Exercise to be avoided—dorsiflexion.

Dorsiflexion (bending the ankle up).—Tibialis anterior. Extensor hallucis longus. Extensor digitorum longus. Peroneus tertius.

EXAMINATION.—

1. Sitting with lower leg hanging over the edge of the table.
   FAIR muscles should bend the ankle up to a right angle, if not prevented by a short heel cord.
   GOOD muscles should do this against downward pressure on the top of the foot. (Even strength in the four muscles will result in the foot being brought up straight, but in case of unequal power, one side of the foot may be raised higher than the other or held more firmly in that position when resistance is given.)
2. Lying on the affected side.
   POOR muscles should bend the ankle up.

EXERCISES.—For FAIR and GOOD muscles.

1. Sitting on the edge of the table, patient bends the ankle up in dorsiflexion. Instructor should guide the foot straight, if it tends to turn out or in during the movement.
   For POOR muscles.
2. Affected side lying, patient bends the ankle up in dorsiflexion.
3. Back lying, the same exercise.
4. Prone lying, with the lower leg held vertical and the foot pointed in the air, patient bends the ankle in dorsiflexion, pulling the toes down toward the table.
   Deformity resulting from weakness of this group—foot drop.
   Exercise to be avoided—plantar flexion.

INVERSION

Tibialis anterior	Tibialis posterior
Extensor hallucis longus	Flexor hallucis longus

EXAMINATION.—For FAIR and GOOD muscles.
(The lower leg should be held to prevent rotation.)

1. Lying on affected side, patient lifts the forefoot from the table while keeping the heel on the table.
   For POOR muscles.
2. Sitting on the edge of the table, patient turns the foot in.

EXERCISES.—For FAIR or GOOD muscles.

1. Lying on affected side, patient lifts the forefoot from the table.
2. Sitting on the edge of the table, patient turns the foot in against resistance.

2. Side lying position, with hips passively flexed, attempt to bend head down to knees. Assistance may be given to lessen friction of table by placing the examiner's hand under the patient's shoulder.
3. Back lying, abdominal retraction. Flattening should not be obtained by elevation of the chest.

FIG. 35.—Test for "normal" anterior abdominal muscles.

4. Back lying, forcible exhalation of a deep breath, as in attempting to blow up a balloon.
5. Using hip flexors, back lying, flex hips and draw knees up to chest, attempting to raise hips from table.

Lateral Flexion.—Obliquus externus and internus. Quadratus lumborum. Rectus abdominis. Erector spinae. Latissimus dorsi of side to which lateral movement takes place.

EXAMINATION.—

1. Lying on the opposite side with legs and pelvis held down firmly by the examiner, the patient raises head and shoulders from the table. A fixed scoliosis will make this test of little value.
2. Back lying, trunk flexion to side, pelvis held fixed.
3. Back or prone lying, patient attempts to draw hip toward ribs of the same side without flexing hip or knee. It is sometimes possible to distinguish the difference in strength between the quadratus lumborum and the lateral abdominal muscles in this test.

EXERCISES.—Same as above.

FLEXION

Toes.—Flexor hallucis longus—distal phalanx of the great toe. Flexor digitorum longus—distal phalanges of four lesser toes. Flexor hallucis brevis—first phalanx of great toe. Abductor and adductor hallucis—first phalanx of great toe. Lumbricales and interossei—first phalanges of four lesser toes. Flexor digitorum brevis—middle phalanges of four lesser toes.

Examination and Exercise.—

1. Sitting or lying, patient curls the toes under, bending all three joints to insure action of all the muscles mentioned. The amount of strength can be judged by placing a finger across under the toes and offering resistance at the different joints. It is not uncommon to find that the middle and terminal joints can be flexed by the long flexors, without any bending of the first joints; or the first joints may bend without any curling of the ends.

Trunk.—Rectus abdominis. Quadratus lumborum. Obliquus externus and internus.

Examination.—

1. Lying on back, feet held down, patient raises head and shoulders, flexing spine in coming to a sitting position. This should be possible for a normal child, with the hands on top of his head, but may not be possible for an adult of poor general muscular tone unless assistance is given. In a child, the anterior abdominal muscles may be rated FAIR if shoulders can be raised from table; GOOD if he can come to sitting position with arms folded on chest. Good anterior neck muscles are required to raise the head in this test, and their severe weakness, allowing the head to hang a dead weight, sometimes makes it difficult to judge the strength of fairly good abdominal muscles. The last part of the movement of coming to an erect sitting position is accomplished by flexion of the pelvis on the thighs by the hip flexors. Strong hip flexor action with weak abdominal muscles will result in flexing the pelvis and arching the lumbar spine without trunk raising, or in accomplishing the sitting position with the lumbar spine first fixed in hyperextension by the erector spinae muscles.
2. Lying on back, pulling in the abdominal muscles, while examiner feels their firmness.

Exercises.—

1. Same as first examination. May be given with assistance, with hands at hips, folded on chest, at neck or on top of head, to increase the difficulty. May be started from half-lying position to make easier. If undesirable to exercise hip flexors, should raise the head and thorax only.

humerus starting from the hanging position is advanced forward, flexed, to the horizontal line, and thence it is elevated to the vertical position; on the return journey the humerus is depressed through 180 degrees to the hanging position, and then it can be carried backward "hyperextended." In the lateral plane, the hanging humerus can be abducted to the horizontal line and thence elevated to the vertical position, and on the return journey it is adducted through 180 degrees to the hanging position. In the horizontal plane, the humerus is horizontally adducted when it is moved from the lateral plane toward the middle line and horizontally abducted when away from the middle line to the lateral plane, behind which it is horizontally retracted. Besides these movements there is rotation in and out.

In "flexing" the humerus, the anterior fibers of the deltoid, the clavicular fibers of the pectoralis major, the biceps, and probably the coracobrachialis contract and carry the humerus forward nearly to the horizontal line. This action of the deltoid tends to rotate the scapula with the acromion downward, and to push its inferior angle backward and toward the spinal column, but this is prevented by the contraction of the acromion (middle) fibers of the trapezius and also the lower fibers. The deltoid and other muscles cannot carry the humerus further than the horizontal line. Beyond this point the serratus magnus comes to their assistance and draws the lower end of the scapula forward, raises the acromion with the humerus, and thus the arm is elevated to the vertical.

In a case with paralyzed lower and middle trapezius, and normal serratus, on telling the patient to advance the arm slowly, the first action on the scapula was to rotate it so that the inferior angle moved half an inch toward the vertebral column, and the posterior border of the scapula projected like a wing; this projection reached its maximum when the humerus was advanced through about 45 degrees. Then the serratus contracted, and as it drew the lower end of the scapula forward the deformity diminished and finally disappeared. Though the serratus is mechanically in the position to fix the scapula and prevent its lower angle being pushed backward and rotated toward the spine, it is not its function when the movement is one of advancing the shoulder to act on the scapula until the humerus has been moved by the deltoid through about 45 degrees. The inferior part of the trapezius apparently is the proper muscle to fix the scapula in advancing the humerus, and when these inferior fibers are paralyzed, the serratus will not step into the breach and do the work for the trapezius, which consequently is not done at all.

The above description of advancing the humerus applies equally well to movement of "abduction" of the humerus, except that the middle part of the deltoid, and the supraspinatus abduct the humerus, and the pectoralis major does not act, but the same condition is met with in regard to movements of the scapula and its relation to the trapezius and serratus, as in flexing the humerus.

EXTENSION

Erector spinae group

Examination.—Prone lying, trunk raising. Accompanied by tightening of hip extensors and trapezius, head raising and scapulae adduction.

Exercises.—

1. Prone lying, legs held down, trunk raising. May be done with hands clasped behind back, at hips, at shoulders, or behind neck, to increase difficulty.
2. Side lying, starting from curled-up position, straightening of head and trunk.
3. Sitting with trunk bent forward, patient comes to erect position.
4. Sitting in erect position, patient lowers trunk forward from hips without bending spine, and then returns to erect position.

Neck.—Sternocleidomastoids.

Examination.—

1. Back lying, shoulders held down, head raising from table. These muscles acting together should be able to hold the head in the raised position against considerable pressure, if normal.
2. To test them separately, lying on back, patient turns face to right side against resistance at point of chin, as test for left muscle.

Exercises.—

1 and 2. Same as above.

3. Lying on back, patient bends head toward shoulder of side it is desired to exercise.
4. Lying on side, patient bends head forward.

As it is not possible to observe or feel the action of the deeper neck muscles, no attempt is made to describe their action. In general, whatever function is weak should be given as an exercise.

The platysma is frequently seen standing out in a broad sheet when the attempt is made to raise the head with weak sternocleidomastoid muscles. The cervical spine and the head are fixed by the extensor muscles, and the attempt is made to raise the head by raising the trunk with the abdominal muscles in many cases of weakness of the anterior neck muscles.

Shoulder Movements *

The movements of the humerus are best described in terms of the planes corresponding to the three dimensions of space, viz., anteroposterior, laterovertical, horizontal. In the anteroposterior plane, the

* Extracts from Croonian Lectures on "Muscular Movements and Their Representation in the Central Nervous System," by Charles Beevor.

Extension of Humerus (bringing arm down from flexion).—Pectoralis major (sternal part). Latissimus. Teres major and minor. Infraspinatus. Triceps, long head. Subscapularis (probably).

Hyperextension (carrying arm back of body).—Latissimus. Teres major and minor. Infraspinatus. Deltoid (posterior part).

Scapula fixed as in adduction.

Horizontal Adduction of Humerus (starting from position of abduction, bringing arm forward at shoulder level).—Pectoralis major (both parts). Anterior deltoid. Coracobrachialis.

Horizontal Abduction of Humerus (carrying arm back at shoulder level).—Posterior and middle deltoid. Latissimus. Teres major and minor. Infraspinatus.

Scapula adducted and fixed by trapezius (middle).

External Rotation of Humerus.—Teres mino:. Infraspinatus. Posterior part of deltoid.

Internal Rotation.—Pectoralis major. Teres major. Latissimus. Subscapularis. Anterior portion of deltoid.

Elevation of Shoulder (shrugging).—Upper part of trapezius. Rhomboids. Levator anguli scapulae.

Depression of Shoulder.—Lower part of trapezius. Pectoralis minor. Latissimus dorsi. Subclavius.

Since each shoulder muscle takes part in several movements, it is necessary to know which of these movements is performed mainly by the muscle we desire to test, and often it is necessary to know the strength of the assisting muscles, before forming our opinion by a process of elimination. Some of the shoulder and arm muscles have to be graded by observation of the strength of the action rather than by gravity tests.

Trapezius.—May be considered in four parts:

1. Clavicular } upper
2. Acromial }
3. Middle—horizontal fibers
4. Lower

It is very difficult to separate the action of the upper two portions, unless there is marked difference in strength. In most cases the acromial and clavicular portions may be considered together as the "upper."

Clavicular—extension of head, rotation of head to opposite side, flexion of head to same side, elevation of shoulder.

In paralysis of the trapezius, the inferior angle of the scapula in the first part of the movement of abduction moves more toward the spine and does not project so much backward as in flexing the humerus. Normally, in advancing the arm, the scapula hardly moves at all until the humerus makes an angle of about 45 degrees, and then the inferior angle begins to move outward by the commencing action of the serratus, and when the humerus is horizontal, the angle with the scapula remains constant, and the elevation of the humerus to vertical is completed by the serratus. If, however, the deltoid be paralyzed or the shoulder be ankylosed, the serratus begins to act at once and the scapula moves outward at once.

The projection or winging of the scapula may be caused by paralysis of the trapezius and especially of its lower fibers, as well as by paralysis of the serratus. The difference is that the deformity due to absence of the trapezius is less than that of the serratus, the scapula projecting only one-half to one inch, that the projection reaches its maximum when the humerus is advanced through about 45 degrees, after which the deformity diminishes and disappears when the humerus is horizontal, and that the humerus can be raised to vertical. With serratus paralysis, the deformity increases as the arm is advanced and reaches its maximum when the humerus is horizontal, above which there is no muscular power to raise it. In serratus paralysis, the scapula can be displaced backward by pushing against the advanced arm.

Flexion (raising arm forward).—Anterior deltoid. Coracobrachialis. Biceps. Clavicular part of pectoralis major.

1. During the first part of flexion, the lower, middle, and acromial portions of the trapezius contract to fix the scapula and prevent its being displaced backward; when the humerus approaches to the horizontal line, the serratus magnus rotates the scapula upward, and the humerus is carried on up to vertical by this rotation.
2. Abduction of humerus to horizontal, in laterovertical plane. Started by supraspinatus; at 10 or 15 degrees the anterior and middle parts of the deltoid begin to act, aided by the long head of the biceps.

   Abduction above horizontal line, muscle action is the same as in flexion above horizontal.

Adduction (of humerus to side).—Pectoralis major, sternal and clavicular parts. Latissimus dorsi. Teres major and minor. Infraspinatus. Posterior part of deltoid. Subscapularis (probably).

The scapula is fixed during movement of the arm by rhomboids, pectoralis minor, and lower part of trapezius.

Extension of Humerus (bringing arm down from flexion).—Pectoralis major (sternal part). Latissimus. Teres major and minor. Infraspinatus. Triceps, long head. Subscapularis (probably).

Hyperextension (carrying arm back of body).—Latissimus. Teres major and minor. Infraspinatus. Deltoid (posterior part).

Scapula fixed as in adduction.

Horizontal Adduction of Humerus (starting from position of abduction, bringing arm forward at shoulder level).—Pectoralis major (both parts). Anterior deltoid. Coracobrachialis.

Horizontal Abduction of Humerus (carrying arm back at shoulder level).—Posterior and middle deltoid. Latissimus. Teres major and minor. Infraspinatus.

Scapula adducted and fixed by trapezius (middle).

External Rotation of Humerus.—Teres minor. Infraspinatus. Posterior part of deltoid.

Internal Rotation.—Pectoralis major. Teres major. Latissimus. Subscapularis. Anterior portion of deltoid.

Elevation of Shoulder (shrugging).—Upper part of trapezius. Rhomboids. Levator anguli scapulae.

Depression of Shoulder.—Lower part of trapezius. Pectoralis minor. Latissimus dorsi. Subclavius.

Since each shoulder muscle takes part in several movements, it is necessary to know which of these movements is performed mainly by the muscle we desire to test, and often it is necessary to know the strength of the assisting muscles, before forming our opinion by a process of elimination. Some of the shoulder and arm muscles have to be graded by observation of the strength of the action rather than by gravity tests.

Trapezius.—May be considered in four parts:

1. Clavicular } upper
2. Acromial }
3. Middle—horizontal fibers
4. Lower

It is very difficult to separate the action of the upper two portions, unless there is marked difference in strength. In most cases the acromial and clavicular portions may be considered together as the "upper."

Clavicular—extension of head, rotation of head to opposite side, flexion of head to same side, elevation of shoulder.

Acromial —rotates acromion process upward, elevates scapula.
Middle —fixes and adducts scapula in horizontal abduction of humerus.
Lower —(a) fixes scapula during flexion or abduction of humerus; paralysis is shown by displacement of inferior angle of scapula toward vertebrae at the start of these movements; also by winging of vertebral border of scapula; (b) fixes scapula during adduction or depression of humerus, acting with rhomboids and pectoralis minor.

To determine trapezius strength, test head extension, elevation of shoulder, scapulae adduction; watch position of inferior angle of scapula during abduction of humerus, and watch for contraction of the middle and lower fibers during the exercise of trunk raising from the prone position.

Serratus Magnus.—(a) Draws the scapula forward around the chest. (b) Rotates the scapula upward, bringing the lower angle outward.

Examination.—

1. Patient sitting with the arm in abduction at shoulder level. Good muscle should rotate the scapula so that the arm is raised to vertical. (The weight of the arm may be supported by the examiner if the deltoid is not strong enough to hold it.)
2. Sitting with the arm at shoulder level, the patient should reach forward. The examiner should steady the patient's body with one hand, grasp the outstretched arm above the elbow with the other hand and, by pushing the humerus, try to displace the scapula backward. If the serratus magnus is weak, the scapula will be displaced so that its vertebral border approaches the spine.

Exercises.—

1. Sitting or lying, movement of the arm from shoulder level to vertical.
2. Sitting or lying, abduction or flexion of the arm from the side to vertical will bring in the action of the serratus and trapezius, if the scapula is not fixed.
3. Lying face down, with the arm hanging over the edge of the table. (a) Patient may reach down to try to touch the floor, (b) patient may swing the arm to try to catch the end of the table above his head.

Movement.—Abduction of arm.

Muscle.—Deltoid, anterior portion.

EXAMINATION.—

1. Patient sitting, with the scapula held down firmly by the examiner to exclude its rotation, with the resultant raising of the humerus.
   FAIR muscles should raise the arm to shoulder level at the side. To exclude the biceps as much as possible from assisting in the movement, the arm should be raised with the elbow passively flexed, forearm hanging, or with the elbow straight, and the palm down.
   GOOD muscles should raise the arm to the side against downward pressure given above the elbow.
2. Patient lying on his back, with the scapula held down by the examiner.
   POOR muscles should perform all or part of the movement of abduction from the side to shoulder level.

EXERCISES.—For FAIR or GOOD muscles.

1. Sitting, with the scapula held down, patient raises arm from the side to shoulder height.
2. Lying on the opposite side, patient raises the upper arm to shoulder level. Scapula should be kept from rotating.
   For POOR muscle.
3. Lying on the back, scapula held, patient moves the arm from the side to shoulder level.
4. Lying on the back, free movement of the arm from the side to shoulder level and above to the ear.

In any movement of abduction of the arm during which the scapula is not prevented from rotating, the action will not be localized in the deltoid. Instead, the movement will be a combined exercise in which the upward rotators of the scapula also take part and do most of the work if they are stronger than the deltoid.

MUSCLE.—Deltoid, posterior portion. Horizontal abduction.

EXAMINATION.—

1. Patient lies face down, with the arm stretched out in abduction at the shoulder level.
   FAIR muscle should raise the arm from the table.
   GOOD muscle should raise the arm against resistance.
   Normally, the scapula is adducted toward the spine at the same time by the middle portion of the trapezius and the rhomboids. If the arm is raised by the posterior deltoid without this adduction of the scapula, these muscles are weak. On the other hand, the scapula adduction may take place when the posterior deltoid is too weak to lift the arm.
2. POOR muscle should be seen to act when the patient abducts his arm from his side to the level of the shoulders. In this position, the posterior deltoid works to overcome the friction of the table,

Acromial —rotates acromion process upward, elevates scapula.
Middle —fixes and adducts scapula in horizontal abduction of humerus.
Lower —(a) fixes scapula during flexion or abduction of humerus; paralysis is shown by displacement of inferior angle of scapula toward vertebrae at the start of these movements; also by winging of vertebral border of scapula; (b) fixes scapula during adduction or depression of humerus, acting with rhomboids and pectoralis minor.

To determine trapezius strength, test head extension, elevation of shoulder, scapulae adduction; watch position of inferior angle of scapula during abduction of humerus, and watch for contraction of the middle and lower fibers during the exercise of trunk raising from the prone position.

Serratus Magnus.—(a) Draws the scapula forward around the chest. (b) Rotates the scapula upward, bringing the lower angle outward.

Examination.—

1. Patient sitting with the arm in abduction at shoulder level. Good muscle should rotate the scapula so that the arm is raised to vertical. (The weight of the arm may be supported by the examiner if the deltoid is not strong enough to hold it.)
2. Sitting with the arm at shoulder level, the patient should reach forward. The examiner should steady the patient's body with one hand, grasp the outstretched arm above the elbow with the other hand and, by pushing the humerus, try to displace the scapula backward. If the serratus magnus is weak, the scapula will be displaced so that its vertebral border approaches the spine.

Exercises.—

1. Sitting or lying, movement of the arm from shoulder level to vertical.
2. Sitting or lying, abduction or flexion of the arm from the side to vertical will bring in the action of the serratus and trapezius, if the scapula is not fixed.
3. Lying face down, with the arm hanging over the edge of the table.
   (a) Patient may reach down to try to touch the floor,
   (b) patient may swing the arm to try to catch the end of the table above his head.

Movement.—Abduction of arm.

Muscle.—Deltoid, anterior portion.

although the middle portion of the muscle has more to do with abducting the arm.

EXERCISES.—

1. FAIR OR GOOD muscle should perform the same movement used in examination position No. 1.
2. POOR muscle should perform the movement used in examination position No. 2.
3. POOR muscle, sitting with the arm stretched out in front of his face, resting on a table at the height of his shoulders, patient moves the arm back until it is in line with his shoulders at the side—horizontal abduction.

MUSCLE.—Latissimus dorsi, hyperextension with internal rotation.

EXAMINATION.—

1. Lying face down.
   FAIR muscle should raise the arm from the table, keeping it close to the side and inwardly rotated.
   GOOD muscle should perform the above movement against resistance.
2. POOR muscle should adduct the arm to the side from a starting position of abduction at shoulder level.

EXERCISES.—

1. For FAIR and GOOD muscles 2. For POOR muscles	The same movement as described in the examination.

MUSCLE.—Pectoralis major.

EXAMINATION.—

1. Patient lies on his back, arm out at shoulder level.
   FAIR muscle should raise the arm to vertical above the face, in movement of horizontal adduction. Both sternal and clavicular portions act in this.
   GOOD muscle should perform the above movement against resistance.
2. POOR muscle brings arm to side from shoulder level—adduction movement.
3. Lying or sitting, if the other muscles are strong enough to raise the arm forward in flexion, the clavicular part of the pectoralis major may be made to stand out by resisting the movement of flexion, and the sternal part by resisting the movement of extension.

EXERCISES.—

1. For FAIR or GOOD muscle, use movement described in examination.
2. For POOR muscle, use movement described in examination.

FIG. 36.—Finish of exercise for "poor" deltoid muscle (anterior half). Notice that the scapula is being held.

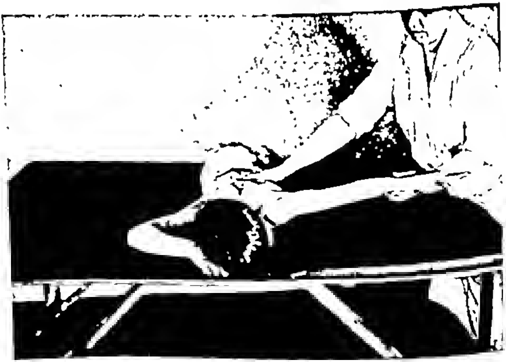

FIG. 37.—"Fair" posterior deltoid.

although the middle portion of the muscle has more to do with abducting the arm.

EXERCISES.—

1. FAIR or GOOD muscle should perform the same movement used in examination position No. 1.
2. POOR muscle should perform the movement used in examination position No. 2.
3. POOR muscle, sitting with the arm stretched out in front of his face, resting on a table at the height of his shoulders, patient moves the arm back until it is in line with his shoulders at the side—horizontal abduction.

MUSCLE.—Latissimus dorsi, hyperextension with internal rotation.

EXAMINATION.—

1. Lying face down.
   FAIR muscle should raise the arm from the table, keeping it close to the side and inwardly rotated.
   GOOD muscle should perform the above movement against resistance.
2. POOR muscle should adduct the arm to the side from a starting position of abduction at shoulder level.

EXERCISES.—

1. For FAIR and GOOD muscles }
2. For POOR muscles } The same movement as described in the examination.

MUSCLE.—Pectoralis major.

EXAMINATION.—

1. Patient lies on his back, arm out at shoulder level.
   FAIR muscle should raise the arm to vertical above the face, in movement of horizontal adduction. Both sternal and clavicular portions act in this.
   GOOD muscle should perform the above movement against resistance.
2. POOR muscle brings arm to side from shoulder level—adduction movement.
3. Lying or sitting, if the other muscles are strong enough to raise the arm forward in flexion, the clavicular part of the pectoralis major may be made to stand out by resisting the movement of flexion, and the sternal part by resisting the movement of extension.

EXERCISES.—

1. For FAIR or GOOD muscle, use movement described in examination.
2. For POOR muscle, use movement described in examination.

3. For POOR muscle, sitting with his arm resting on a table at shoulder height, out in position of abduction, patient brings the arm forward in horizontal adduction.

Movement.—Outward rotation.

MUSCLES.—Teres minor. Infraspinatus. Deltoid, posterior part.

EXAMINATION.—

1. Lying face down, with the upper arm out at shoulder level and the forearm hanging over the edge of the table, with the elbow bent at a right angle.
   FAIR muscles should rotate the upper arm outward, thus raising the hand and forearm above the level of the table.
   GOOD muscles can hold the arm in this position against downward pressure on the forearm.
2. Lying on the back, with arm at the side.
   POOR muscles should turn the arm outward at the shoulder, rolling the elbow back. The elbow must be watched to make sure that the upper arm turns as well as the hand and forearm.

EXERCISES.—For FAIR or GOOD muscles.

1. Use position described in examination of these muscles.
2. Sitting with the upper arm and forearm supported at shoulder level, elbow flexed to a right angle, arm in abduction, patient raises forearm, thus performing outward rotation at the shoulder.

For POOR muscles.

3. Use position and movement described in examination of poor muscles.
4. Lying face down with the whole arm hanging over the edge of the table, elbow straight, patient turns the whole arm outward.

ARM AND HAND MOVEMENTS

Movement.—Elbow flexion.

MUSCLES.—Biceps. Brachialis. Brachioradialis. Pronator teres. Flexors of the wrist. Flexor digitorum sublimis.

EXAMINATION.—

1. Patient sits with the arm hanging at the side.
   FAIR muscles should raise the forearm so that the hand touches the shoulder.
   GOOD muscles raise the forearm against resistance.
2. Patient sits with the whole arm supported on a table, elbow straight, hand resting on the fifth finger.
   POOR muscles bend the elbow without raising the forearm from the table.

The biceps is the strongest flexor and acts with the palm turned toward the patient's face—that is, with the forearm in supination. Inability to flex the elbow with the forearm in this position indicates weakness of the biceps, and exercises should be directed toward its development, since the other *elbow flexors* cannot make up for its loss.

Exercises.—For fair and good muscles.

1. Patient sitting, with his arm hanging, touches his fingers to his shoulder.

   For poor muscles.
2. Sitting with the entire arm supported on the table at shoulder height, elbow straight, hand resting on the fifth finger, patient bends the elbow, drawing the forearm along the table.
3. Lying on the back with the entire arm supported vertically in the air, patient bends the elbow, pulling the hand down toward the face with the aid of gravity, against the resistance of the examiner's supporting hand. The upper arm must be held vertical by mother throughout.

Movement.—Elbow extension.

Muscles.—Triceps. Anconeus.

Examination.—

1. Lying on the back, or sitting erect, with the upper arm held vertical, the elbow flexed and the forearm hanging.

   Fair muscles should straighten the elbow, raising the forearm to vertical.

   Good muscles should raise the forearm in this position against some downward pressure from the examiner.
2. Lying on the back, or sitting, with the entire arm resting flat on the table, elbow bent.

   Poor muscles should perform at least part of the movement of straightening the elbow.

Exercises.—For fair and good muscles.

1. Patient straightens his elbow in the same position used for grading these muscles.

   For poor muscles.
2. With the arm and forearm resting on a table, patient attempts to straighten the bent elbow.
3. Sitting, hand touching shoulder, patient pushes his forearm downward against sufficient resistance to neutralize the weight of the arm.

3. For POOR muscle, sitting with his arm resting on a table at shoulder height, out in position of abduction, patient brings the arm forward in horizontal adduction.

Movement.—Outward rotation.

MUSCLES.—Teres minor. Infraspinatus. Deltoid, posterior part.

EXAMINATION.—

1. Lying face down, with the upper arm out at shoulder level and the forearm hanging over the edge of the table, with the elbow bent at a right angle.
   FAIR muscles should rotate the upper arm outward, thus raising the hand and forearm above the level of the table.
   GOOD muscles can hold the arm in this position against downward pressure on the forearm.
2. Lying on the back, with arm at the side.
   POOR muscles should turn the arm outward at the shoulder, rolling the elbow back. The elbow must be watched to make sure that the upper arm turns as well as the hand and forearm.

EXERCISES.—For FAIR or GOOD muscles.

1. Use position described in examination of these muscles.
2. Sitting with the upper arm and forearm supported at shoulder level, elbow flexed to a right angle, arm in abduction, patient raises forearm, thus performing outward rotation at the shoulder.
   For POOR muscles.
3. Use position and movement described in examination of poor muscles.
4. Lying face down with the whole arm hanging over the edge of the table, elbow straight, patient turns the whole arm outward.

ARM AND HAND MOVEMENTS

Movement.—Elbow flexion.

MUSCLES.—Biceps. Brachialis. Brachioradialis. Pronator teres. Flexors of the wrist. Flexor digitorum sublimis.

EXAMINATION.—

1. Patient sits with the arm hanging at the side.
   FAIR muscles should raise the forearm so that the hand touches the shoulder.
   GOOD muscles raise the forearm against resistance.
2. Patient sits with the whole arm supported on a table, elbow straight, hand resting on the fifth finger.
   POOR muscles bend the elbow without raising the forearm from the table.

EXAMINATION.—

1. Patient sitting with the palm of the hand resting on the table. FAIR extensors should raise the hand from the table. GOOD muscles would overcome resistance as well. The fingers should not be held in extension unless it is desired to have the finger extensors assist in the movement.
2. With the ulnar side of the forearm and hand resting on the table, POOR extensors should bend the wrist back in extension.

EXERCISES.—These are given in the same positions as in the examination.

Movement.—Wrist abduction.

MUSCLES.—Flexor and extensor carpi radialis. Extensors of the thumb.

EXAMINATION AND EXERCISE.—Hand resting on the table, palm up. Patient bends the wrist toward the thumb side, without moving forearm.

Movement.—Wrist adduction.

MUSCLES.—Flexor and extensor carpi ulnaris.

EXAMINATION AND EXERCISE.—Patient bends the wrist toward the ulnar side, without moving forearm. These lateral movements are used chiefly when inequality exists between the radial and ulnar muscles.

Movement.—Finger extension.

MUSCLES.—Extensor digitorum communis, extends the proximal phalanges.

EXAMINATION AND EXERCISE.—Patient pushes back the proximal phalanges of the four fingers, either alone or against resistance, keeping middle and end joints flexed loosely.

Movement.—Finger extension.

MUSCLES.—Interossei and lumbricales, extend the second and third phalanges.

EXAMINATION.—Patient extends the middle and end joints of the fingers, either alone or against resistance. The first phalanges should be held by the examiner in extension during the movement. If the first phalanges are held passively flexed, the extensor digitorum communis can extend the second and third phalanges without the interossei and lumbricales.

Movement.—Supination of forearm.

MUSCLES.—Biceps. Supinator brevis. Brachioradialis.

EXAMINATION AND EXERCISE.—Sitting with the elbow flexed to a right angle, palm turned down, patient turns the forearm, palm up.
Resistance to the movement may be given by grasping the forearm just above the wrist.

Movement.—Pronation of forearm.

MUSCLES.—Pronator radii teres. Pronator quadratus. Flexor carpi radialis.

EXAMINATION AND EXERCISE.—Sitting with the elbow flexed to a right angle, palm up, patient turns the forearm, palm down. Resistance as for supination.

Movement.—Wrist flexion.

MUSCLES.—Flexor carpi radialis. Palmaris longus. Flexor carpi ulnaris. Long flexors of the fingers and thumb.

EXAMINATION.—

1. Patient sitting with the back of the hand resting on the table. FAIR flexors should bend the wrist, palm up, raising the hand against gravity.
   GOOD muscles would overcome resistance as well.
   The fingers should be relaxed to localize the action in the other muscles.
2. Sitting with the ulnar side of the forearm and hand resting on the table, midway between pronation and supination.
   POOR flexors should bend the wrist, gravity being eliminated.
   It will be necessary for the examiner to feel the different tendons to know what part each muscle is taking in the movement.

EXERCISES.—For GOOD, FAIR or POOR flexors.

1 and 2. These are given in the same positions as the test Nos. 1 and 2.

3. For POOR muscles, with the forearm resting on the table in pronation, hand extending over the table edge, patient bends the wrist downward against enough resistance to neutralize the weight of the hand.

Movement.—Wrist extension.

MUSCLES.—Extensor carpi radialis longus and brevis. Extensor carpi ulnaris. Long extensors of fingers and thumb.

EXAMINATION.—

1. Patient sitting with the palm of the hand resting on the table.
   FAIR extensors should raise the hand from the table.
   GOOD muscles would overcome resistance as well.
   The fingers should not be held in extension unless it is desired to have the finger extensors assist in the movement.
2. With the ulnar side of the forearm and hand resting on the table, POOR extensors should bend the wrist back in extension.

EXERCISES.—These are given in the same positions as in the examination.

Movement.—Wrist abduction.

MUSCLES.—Flexor and extensor carpi radialis. Extensors of the thumb.

EXAMINATION AND EXERCISE.—Hand resting on the table, palm up. Patient bends the wrist toward the thumb side, without moving forearm.

Movement.—Wrist adduction.

MUSCLES.—Flexor and extensor carpi ulnaris.

EXAMINATION AND EXERCISE.—Patient bends the wrist toward the ulnar side, without moving forearm. These lateral movements are used chiefly when inequality exists between the radial and ulnar muscles.

Movement.—Finger extension.

MUSCLES.—Extensor digitorum communis, extends the proximal phalanges.

EXAMINATION AND EXERCISE.—Patient pushes back the proximal phalanges of the four fingers, either alone or against resistance, keeping middle and end joints flexed loosely.

Movement.—Finger extension.

MUSCLES.—Interossei and lumbricales, extend the second and third phalanges.

EXAMINATION.—Patient extends the middle and end joints of the fingers, either alone or against resistance. The first phalanges should be held by the examiner in extension during the movement. If the first phalanges are held passively flexed, the extensor digitorum communis can extend the second and third phalanges without the interossei and lumbricales.

Movement.—Supination of forearm.

MUSCLES.—Biceps. Supinator brevis. Brachioradialis.

EXAMINATION AND EXERCISE.—Sitting with the elbow flexed to a right angle, palm turned down, patient turns the forearm, palm up.
Resistance to the movement may be given by grasping the forearm just above the wrist.

Movement.—Pronation of forearm.

MUSCLES.—Pronator radii teres. Pronator quadratus. Flexor carpi radialis.

EXAMINATION AND EXERCISE.—Sitting with the elbow flexed to a right angle, palm up, patient turns the forearm, palm down. Resistance as for supination.

Movement.—Wrist flexion.

MUSCLES.—Flexor carpi radialis. Palmaris longus. Flexor carpi ulnaris. Long flexors of the fingers and thumb.

EXAMINATION.—

1. Patient sitting with the back of the hand resting on the table. FAIR flexors should bend the wrist, palm up, raising the hand against gravity.
   GOOD muscles would overcome resistance as well.
   The fingers should be relaxed to localize the action in the other muscles.
2. Sitting with the ulnar side of the forearm and hand resting on the table, midway between pronation and supination.
   POOR flexors should bend the wrist, gravity being eliminated.
   It will be necessary for the examiner to feel the different tendons to know what part each muscle is taking in the movement.

EXERCISES.—For GOOD, FAIR or POOR flexors.

1 and 2. These are given in the same positions as the test Nos. 1 and 2.

3. For POOR muscles, with the forearm resting on the table in pronation, hand extending over the table edge, patient bends the wrist downward against enough resistance to neutralize the weight of the hand.

Movement.—Wrist extension.

MUSCLES.—Extensor carpi radialis longus and brevis. Extensor carpi ulnaris. Long extensors of fingers and thumb.

Examination.—

1. Patient sitting with the palm of the hand resting on the table.
   Fair extensors should raise the hand from the table.
   Good muscles would overcome resistance as well.
   The fingers should not be held in extension unless it is desired to have the finger extensors assist in the movement.
2. With the ulnar side of the forearm and hand resting on the table, poor extensors should bend the wrist back in extension.

Exercises.—These are given in the same positions as in the examination.

Movement.—Wrist abduction.

Muscles.—Flexor and extensor carpi radialis. Extensors of the thumb.

Examination and Exercise.—Hand resting on the table, palm up. Patient bends the wrist toward the thumb side, without moving forearm.

Movement.—Wrist adduction.

Muscles.—Flexor and extensor carpi ulnaris.

Examination and Exercise.—Patient bends the wrist toward the ulnar side, without moving forearm. These lateral movements are used chiefly when inequality exists between the radial and ulnar muscles.

Movement.—Finger extension.

Muscles.—Extensor digitorum communis, extends the proximal phalanges.

Examination and Exercise.—Patient pushes back the proximal phalanges of the four fingers, either alone or against resistance, keeping middle and end joints flexed loosely.

Movement.—Finger extension.

Muscles.—Interossei and lumbricales, extend the second and third phalanges.

Examination.—Patient extends the middle and end joints of the fingers, either alone or against resistance. The first phalanges should be held by the examiner in extension during the movement. If the first phalanges are held passively flexed, the extensor digitorum communis can extend the second and third phalanges without the interossei and lumbricales.

Extensor indicis proprius and extensor digiti quinti proprius assist the extensor communis to extend their respective fingers, but either may act in the absence of the common extensor.

Movement.—Finger flexion.

MUSCLES.—Those of *first* phalanges, mainly interossei and lumbricales.

EXAMINATION.—Patient should be tested with fingers outstretched. Movement is aided by flexor digitorum sublimis and flexor digitorum profundus if fingers are allowed to flex.
Those of *second* phalanges, flexor digitorum sublimis and flexor digitorum profundus.
Those of *third* phalanges, flexor digitorum profundus.

Movement.—Adduction of fingers, to middle finger.

MUSCLES.—Palmar interossei.

1st	palmar interosseus adducts	index finger
2nd	" " "	fourth "
3rd	" " "	fifth "

EXAMINATION AND EXERCISE.—Be careful to avoid flexing at same time.

Movement.—Abduction of fingers—from an imaginary line drawn through the middle finger.

MUSCLES.—Dorsal interossei. Abductor digiti minimi.

1st	dorsal interosseus abducts	index finger
2nd	" "	moves middle finger toward index finger
3rd	" "	" " " " fourth "
4th	" "	" fourth " " fifth "

Abductor digiti minimi abducts fifth finger.

EXAMINATION AND EXERCISE.—Have patient spread all fingers apart, or each separately, and hold the position. Fingers should be kept flat during movement.

Movement.—Thumb extension.

MUSCLES.—Extensor pollicis longus—first the terminal joint, then the proximal joint, and the carpometacarpal. Extensor pollicis brevis—proximal joint and carpometacarpal. Extensor ossis metacarpi pollicis (abductor longus)—carpometacarpal joint.

Movement.—Thumb flexion.

MUSCLES.—Flexor pollicis longus—all three joints, especially the terminal one. Flexor pollicis brevis—metacarpal bone and first

phalanx. Opponens pollicis—metacarpal bone. Abductor pollicis brevis—metacarpal bone. Adductor pollicis—metacarpal bone.

EXAMINATION.—Patient flexes thumb across the palm, keeping thumb flat to palm.

Movement.—Thumb opposition.

MUSCLES.—Opponens pollicis. Flexor pollicis brevis. Abductor pollicis brevis. Adductor pollicis.

EXAMINATION.—

Patient abducts thumb at right angles to palm, and then approximates it to fingers and ulnar side of hand, keeping a space open between the thumb and the palm.

Atrophy of both the abductor brevis and opponens pollicis produces a general flattening of the thenar eminence. Atrophy mainly of the opponens pollicis is shown by a hollow along the metacarpal bone on the radial side of the thenar eminence.

FACIAL PARALYSIS AND THROAT

The following movements should be tried and practiced as exercises, before a mirror if needed. The two sides of the face should be carefully compared. In the case of unilateral weakness, there will be more movement on the stronger side. This will be especially noticeable in laughing

FIG. 38.—Case showing permanent facial and nasal deviation 15 years after onset

Fig. 39.—Right facial involvement.

and crying, as the mouth, cheek and nostril are drawn to that side, producing a grotesque expression which the patient may erroneously attribute to trouble with the stronger side.

1. Raise the eyebrows, wrinkling the forehead.
2. Scowl, drawing the eyebrows together.
3. Close the eyes.
4. Open the eyes wide.
5. Turn the eyeballs from side to side.
6. Wrinkle the nose and sniff.
7. Smile; notice the corners of the mouth as well as the cheek.
8. Pucker the lips to whistle.
9. Open the mouth, dropping the jaw evenly.
10. Close the mouth with pressure, as in chewing.
11. Move the lower jaw from one side to the other.
12. Run the tongue out straight.
13. With the mouth open, notice whether the arch of the soft palate is the same on both sides, and whether it is lifted equally when the patient says "a·ah." In addition to sagging on the paralyzed side, the uvula may be drawn to the stronger side.

Any difficulty with speech, swallowing, raising mucus, coughing or sneezing should be noted.

Respiration

It is difficult to grade the strength of the muscles of respiration, but varying degrees of paralysis, which may be unilateral or bilateral, are often detected in the after-care of patients who have had acute respiratory involvement in the early stages of the disease. Careful observation of the movements of the abdomen and of the chest wall is essential in order to determine whether the breathing is being carried on mostly by the diaphragm or by the intercostal muscles, and whether it is alike on both sides. A fluoroscopic examination will sometimes be of assistance in showing the amount of excursion of the diaphragm on the two sides.

A normal child, lying quietly, moves the chest very little in ordinary breathing. With each inspiration, there is a slight bulging of the abdomen from the increased pressure caused by the descent of the diaphragm. When asked to take a deep breath, the chest is raised, but normal children often fail to show more than one-half inch chest expansion unless they have been trained to do breathing exercises. For this reason, too much significance should not be attached to small chest expansion in a poliomyelitis patient, unless there is a history of respiratory involvement, or unless there are obvious signs of unusual activity of the accessory muscles in the effort to lift the chest.

Diaphragm.—

1. Observation of an unusual amount of chest expansion on each inspiration, accompanied by a sucking-in of the upper abdomen, indicates severe weakness of the diaphragm.
2. The examiner may hold the patient's ribs firmly, to interfere with the action of the intercostal muscles in attempting to raise the chest, while he observes the abdomen. A strong action of the diaphragm on inhalation will produce a perceptible bulge in the abdominal wall, and respiration will go on without discomfort, in spite of the restricted chest movement.

Intercostals.—

1. In severe paralysis of these muscles, with a good diaphragm, the abdomen bulges markedly on each inspiration, and the chest flattens, particularly in the region of the lower ribs, which are sucked in by the pull of the diaphragm.
2. The examiner holds the lower ribs and the abdomen firmly against motion, and the patient is urged to expand the chest with a deep breath. The scaleni and the sternocleidomastoids normally act to raise the chest in forced inspiration, as do the serrati, pectorals, etc., but their action is much more marked when the intercostals are involved.

Exercises.—

1. The patient should be taught to breathe with whichever muscles do not produce normal excursion on inspiration.
   Pressure on the ribs by the examiner's hands will help to localize the action, by preventing movement at that point and forcing expansion elsewhere.
2. Arm-raising and rib-stretching exercises should be included to prevent contractures which may hold the ribs in a sunken position.
3. Forcible expiration will also be useful.

Equipment for Muscle Training

The only equipment necessary is a table which can be made by any carpenter. It should be large enough to support a patient lying on his back with both legs in full abduction. For many patients, especially children, a somewhat narrower table will be satisfactory if the worker steadies the patient's foot or hand when it is extended over the edge. The exact measurements will differ according to whether or not adults as well as children must be planned for, but it should be possible for the average patient to lie on his side with his hips flexed and the underneath leg extended at a right angle to his body. We have tables five feet, five and one-half and six feet in length, varying in width from three to four feet. It is better not to have them hinged for adjustable back supports, as any cracks or hinges increase friction or pro-

vide an obstacle which has to be avoided. For the same reason drop leaves on a narrower table, which is ordinarily used for other purposes, are not as satisfactory as a solid top. A table of the required size may be built with folding legs and stood against the wall when not in use if the floor space is needed for other purposes.

While a wooden surface may be used, patients will be more comfortable if a few layers of harness felt are laid on the wood, extending over its edges, and this is covered by a smooth leatherette or a waterproof covering which comes for automobile tops.

When it is necessary to give exercises in a bed, it is desirable to have as firm a mattress as possible, both to lessen friction and insure more accurate movements than can be obtained in a soft bed which sags in the middle. Often a board placed under the mattress, or a linoleum-covered board, like a table top, placed under the patient, will make a satisfactory substitute for a table.

It should be emphasized again that it is not the equipment, but the choice of suitable exercises and the technic of giving them, that constitutes efficient treatment of paralyzed muscles. The kitchen table and even the kitchen floor have been utilized many times in homes where no other facilities were available.

Various aids may be devised to assist very weak muscles in producing movements, or to reduce friction. Dusting powder may be used, or slings to support the weight of the limb in exercises such as abduction, with or without the use of pulleys or pendulum weights. A support with a ball-bearing joint is sometimes used for the limb. Such devices may serve to stimulate the interest of the patient, but in most cases the hands of the worker can give more accurate localization of the movement, while at the same time giving the necessary support and assistance.

The action of any mechanical exercises should be very carefully analyzed before consent is given for their use by patients whose muscles are severely paralyzed, or whose muscle balance has been affected. The general criticisms of their use are:

1. Evidences of beginning fatigue cannot be recognized as readily as when the control of a movement is supplied either by the hands of an experienced worker or by a parent who has been accustomed to the reactions of that particular child.
2. Springs or weights may replace the active effort of the particular muscles most in need of exercise, while the stronger antagonists are still further developed.
3. Other muscles may be substituted and the movement performed in a faulty manner.

The danger of overfatigue, and the danger of neglect of scientific treatment on account of the use of some highly advertised mechanical appliance are the most serious arguments against their use.

Therapeutic Exercise Pool

The practice of giving muscle training in an exercise pool will be found beneficial to many patients. Its use seems particularly adapted to those whose muscles are so badly affected that they are able to produce little or no motion of the limbs on a table.

It is customary to say that a muscle examination made in warm water will show a rating one grade higher than can be demonstrated outside. This is because the weight of the limbs is largely supported by the water, and the pull of gravity is either greatly diminished or entirely overcome, so that the part floats. In consequence, less strength is required to move the part, and an easier set of exercises can be evolved which are better graduated for very weak muscles, because they provide the right amount of work without the insensible fatigue of overexertion. Undoubtedly, the patient's enjoyment of the exercise period stimulates him to greater effort and so hastens his progress.

The same care must be given to the choice of exercises suitable to the degree of weakness of the muscles, and to the relative strength of the opposing group, as has been previously described. Equal attention must also be paid to localizing the movements in the desired muscles. The danger of the stronger muscles' neglect of the weaker ones, in general and recreative movements in the water, is just as great as on land. The instructor of normal children in the swimming pool is no more qualified to undertake the treatment of infantile paralysis patients in the water, than the physical education instructor is qualified to treat them in the gymnasium. It is far better to teach the mother just what exercises should be done, either on a table or in the water, than to refer the child to the general swimming pool as a substitute for treatment. The general swimming pool may be of some benefit to the chronic case, as a healthful recreation in which he can participate with others, but it does not constitute efficient treatment and may do definite harm in increasing deformities.

A therapeutic exercise pool of any size has the same problems as any other pool with regard to sterilization of water, overflow drains, cleanliness, etc. Salt water may be used for additional buoyancy but is not necessary.

The pool at the Children's Hospital, Boston, has a recirculation system of continuous flow, liquid chlorine, and triple gravel filters. The laboratory bacteriologic reports are almost sterile, and at an average of 0.3 part per million of residual chlorine, there are very few complaints of irritation to the mucous membranes or eyes.

The water must be kept at a temperature of 90 to 94° F. (32.22 to 34.44° C.), or severely paralyzed patients will complain of cold. While this temperature is uncomfortably warm for normal persons, it should be borne in mind that it is somewhat below body temperature, thus causing a loss of body heat. The cold limbs and poor circulation of paralyzed patients do not have the quick reaction and extra production

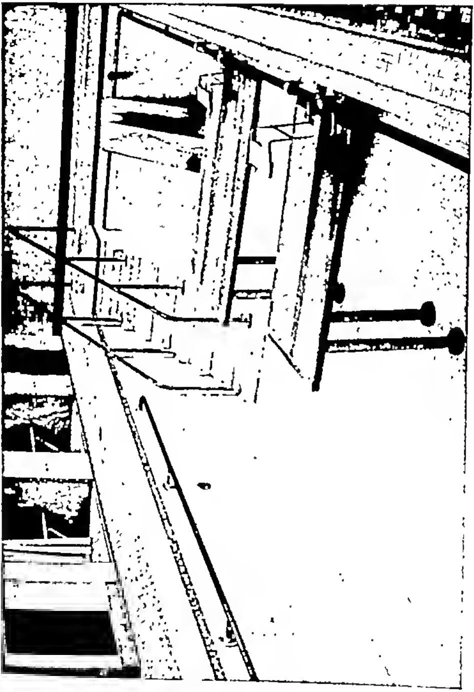

FIG. 40—Pool for muscle training—empty.

Therapeutic Exercise Pool

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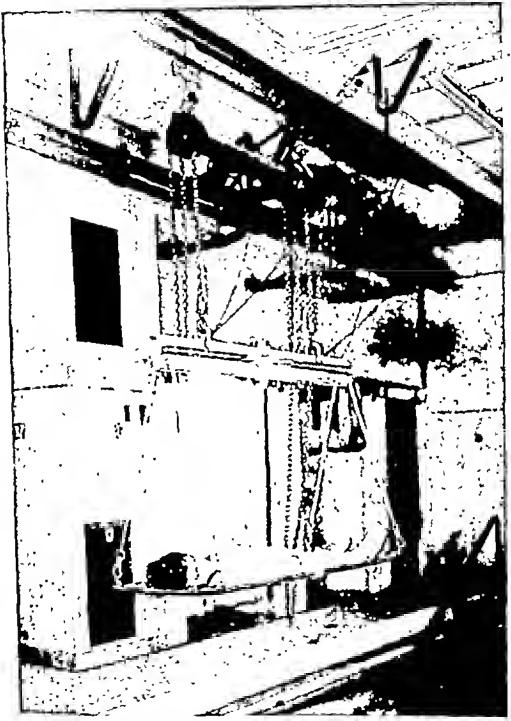

FIG. 41.—Frame carrier and hoist for transportation of severely involved cases from truck to pool

FIG. 41.—Pool for muscle training—filled.

see which ones are best suited to the functional ability of the muscles. Some poor muscles will function best in a movement parallel to the surface of the water, while others accomplish more either in lifting the part toward the surface or in the opposite position of submerging it. The tension of the antagonistic muscles and the ability of the part to float are conditions which affect the difficulty of the exercise.

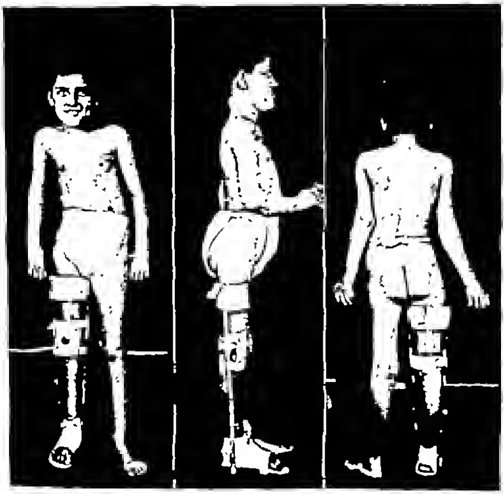

FIG. 44.—Galvanized-iron extension splints applied.

The trunk muscles respond especially well to exercises in water, and a greater variety can be worked out for weak abdominal and back muscles than can be performed on a table.

The balance of the head and trunk in the erect sitting position may be gained by practicing in water which reaches above the shoulders. The patient who has to learn to walk over again, using braces and crutches, makes much faster progress if he has had a preliminary training in the pool. Leg splints and a corset may be worn in the

of heat with which the normal person responds to a lower temperature, and chilling results, with consequent loss of muscle effectiveness.

The routine precautions observed to prevent a spread of infection include nose and throat culture, Wassermann test if the history suggests its need, warm soap scrub on a table under a shower, and careful inspection for signs of a skin infection, a rash or a cold. Ambulatory patients wear paper slippers over bare feet outside the pool.

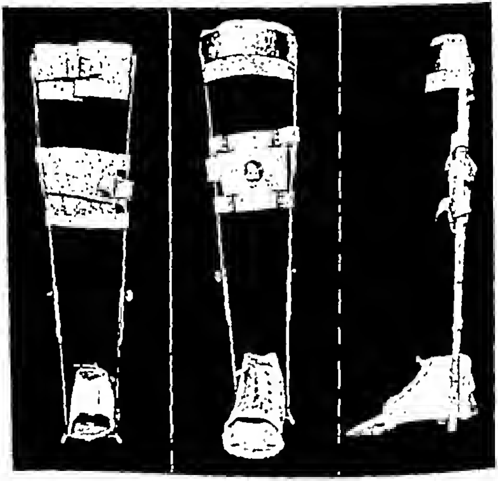

FIG. 43.—Galvanized-iron extension splints for walking in the pool.

A 15- or 20-minute rest should be required after the exercise period. A table submerged in the pool about 10 inches below the surface will be found of assistance in giving many exercises. The legs may be fastened in sockets on the bottom of the pool if it is desired to have the table removable, or one end may be hung from the hand rail with weighted legs at the other end to hold it down. An inclined plinth under water will also be found useful.

Many of the same exercise positions may be used in the water, but it will be found necessary to try out the different positions to

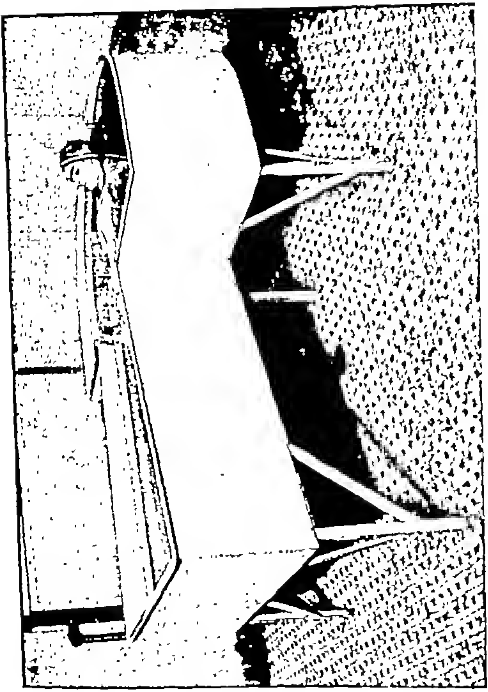

FIG. 46.—Hubbard tub for treating individual cases.

pool to prevent faulty weight bearing. The problem of maintaining the balance, while shifting the weight from side to side as the legs are moved, is made much easier when the body is supported by water of shoulder depth.

Other problems of daily life, such as going up and down stairs and sitting down and getting up out of a chair, may be mastered

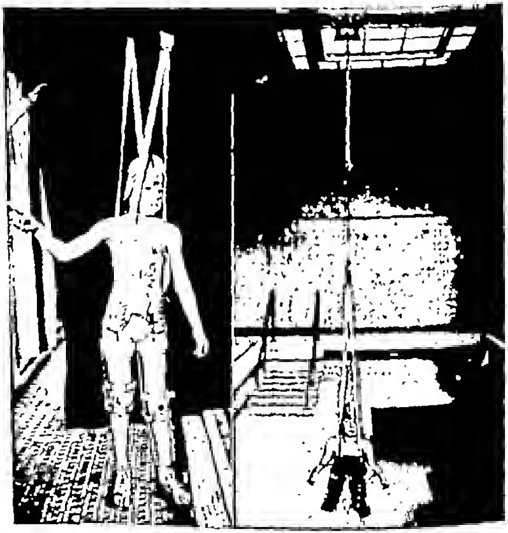

FIG. 45.—Galvanized-iron splints, corset and sling for walking in the pool.

more easily in the water. Low stairs with hand rails extending out some distance under water will be found very useful in helping to make these patients independent.

The use of an exercise tub is of very definite advantage to recently paralyzed patients. Movements can be made without pain in the warm water even before the sensitiveness has gone, and an immediate decrease in sensitiveness is usually noticed when physical therapy treat-

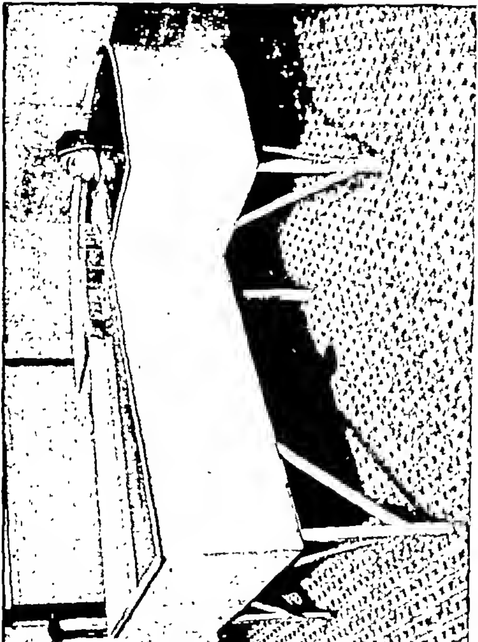

FIG. 46.—Hubbard tub for treating individual cases.

ment is started in this way. Instead of using the large pool, we prefer to submerge such patients on a Bradford-frame in a table tub about 18 inches deep (large enough for one patient). About 100° F. (37.78° C.) is the usual temperature while sensitiveness remains. No attempt is made to force painful movements, or to carry through a list of exercises. The patient is allowed to move as he likes, and confidence is gained in the shallow water. If there are beginning contractures, the patient is encouraged to try to overcome them, but no painful stretching is done. The patient remains in the water about ten minutes and is then lifted on the frame and dried off with as little movement of sensitive joints as possible.

Physical Therapy in Postoperative Conditions

Muscle training after tendon transplantations is of the greatest importance, as the after-treatment may mean the success or failure of the result.

After a tendon transplantation, the part must be immobilized in the corrected or overcorrected position. There is danger that atrophy and weakening of the muscle will take place, if complete immobilization is continued for any considerable length of time. It is essential, however, that time enough should be allowed for the transplanted tendon to become firmly attached to its new insertion, before allowing any motion.

A tendon should be firmly enough attached after twelve or fourteen days to allow some pull to be made upon it. It is my rule to begin baking and superficial massage without motion when the stitches are taken out, usually after eight or ten days. At this time, the patient should also begin to "set" the muscle, making one or two attempts to contract it. After twelve to fourteen days, the number of times the muscle is contracted may be gradually increased, depending upon its response, so that after two weeks regular muscle training is being carried on.

In cases where a tendon has been transplanted to such a place that its new function will be entirely different from the original one, it is often necessary at the start to tell the patient to carry out the former function in order to have him perform the new one. Patients will gradually learn with practice to perform the new function, and as soon as this is accomplished, the original function should be dropped from the list of exercises. If there are other muscles of sufficient strength to initiate the movement, or to assist the transplanted muscle in its new position, it will regain good functional use more quickly.

Great care should always be taken to prevent muscle fatigue from the treatment just as in the muscle training of cases where there has been no operation. A weaker response should be the signal for rest, rather than for repeated efforts to demonstrate the ability to function.

The first postoperative treatments should be given with the part

resting in half of the bivalved plaster. Baking, superficial massage and reëducation of the transplant can be given in this way before it is safe to have the part unsupported. The region of the incision may be left covered by a small dressing if it is not entirely healed, while treatment is given to the rest of the muscle.

Tendons of partially paralyzed muscles must be carefully protected from stretching, and they require a longer period of rest after their attachment in a new position than is necessary after the suture of a divided tendon whose insertion has not been disturbed.

A bone operation, such as a stabilization, must be treated as a fracture, whether or not a muscle transplantation has been done at the same time. Baking and massage may be started in two weeks, provided that care is taken to prevent any motion at the joints operated upon, and muscle training for a transplantation may be added in about four weeks.

It is important to carry on massage and muscle training to keep up the circulation and tone of the affected muscles in other parts of the body during a period of postoperative inactivity. Light work of this kind can usually be started soon after the disappearance of the early postoperative reaction and discomfort, provided that care is taken to avoid any exercise or position which may cause strain on the immobilized part.

When weight bearing has been resumed, much can be done in many cases to improve the patient's gait by special training to overcome faulty habits, and to insure the use of a transplanted muscle in walking. Instruction is often needed to aid the patient in acquiring good balance of the body after stabilization operations on the feet.

Much time can be saved and better results obtained, if an intelligent use is made of physical therapy measures following operative procedures in the treatment of poliomyelitis.

Necessity of Follow-up

The importance of follow-up treatment in the after-care of poliomyelitis is very great.

Since the maximum recovery from the effects of an attack of poliomyelitis can not be obtained in a few weeks or months, if there has been any considerable degree of paralysis, but is a long and tedious process in which the outcome is dependent upon the regular and faithful coöperation of the patient and his family, some thought must be given to the problem of obtaining, and keeping, this coöperation.

The parents of children affected with poliomyelitis should be given an honest, heart-to-heart talk about what they have to expect; and should have it explained to them that no one can tell how much recovery can be made by the weakened muscles, but that whether or not their child regains the maximum amount possible to him depends to a large extent upon their faithfulness in carrying out treatment.

They should understand that there will be periods when no appreciable gain will be made, but that neglect of treatment may allow the development of serious deformities, and that muscles often start in to gain again after a stationary period.

They should also realize that there are charlatans who will promise perfect cures, and that, on the other hand, there are reputable doctors who do not yet realize the improvement that can be gained by carefully planned muscle training and will tell them that it is not worth while to do anything more than wear braces. It is easy to understand the discouragement and the perplexity that the parents of paralyzed children must often feel, and they should be given every legitimate encouragement to carry on, for the good of the child.

Daily treatment by an expert in muscle training, with the frequent supervision of the surgeon, is of course the ideal method of treatment. Obviously this is possible for only a limited number and cannot be arranged for any large group of patients with restricted financial means, who are scattered over a wide area.

Careful instruction of the mother so that she may carry on the proper exercises correctly, in between the days when she reports to the clinic, is the only practical method of follow-up.

It is our policy in the Harvard Infantile Paralysis Commission Clinic to have cases report three times a week to the clinic at the start of their treatment, so that the progress of each muscle may be watched carefully, and the parent instructed in the exercises she should carry out at home on the other days.

It is true that some parents are incapable of understanding and carrying out instructions in muscle training, but a fairly intelligent mother will soon learn to carry out exercises, if she realizes their value, after being shown and made to perform them herself a few times under the direction of a capable worker. These home exercises are of vital importance, for a patient will certainly lose muscle power if the treatment is not carried out daily. For this reason, it is necessary for a clinical physical therapy worker to have the ability to instruct the parents and obtain their coöperation. As the parents learn to carry on correctly without supervision, the patients' visits to the clinic are gradually decreased to once a week, and later to the intervals when it is desirable to have their progress inspected by the surgeon.

It is impossible for many parents to bring the patients to the clinic three times a week. In these cases, they must do the best they can with less frequent instruction and report as often as possible. In order to insure that the treatment of such cases is carried on, and not neglected, any organization doing follow-up work must provide field workers to reach the patients at regular intervals. This may be done to some extent by visits to the homes, or by the institution of so-called treatment clinics which are held by the workers at convenient local centers at weekly, or other, intervals. At these treatment clinics, the worker carries out the same treatment which would have been given at the

hospital clinic and supervises the mother's methods of giving the exercises. She also notices whether the surgeon's instructions are being carried out and later reports to him any change in the patient's condition which requires his attention.

These treatment clinics held near the homes are often more effective in encouraging the parents to continued effort than home visits, since they have the opportunity to see the progress that other children are making, and to hear how other mothers manage to meet the problems of getting in the daily exercise period and of making the children carry out the doctor's other instructions.

After muscle training has gone on for a few weeks, some muscles will be seen to have regained power faster than others. For this reason, it may be advisable to lessen the amount of exercise given these muscles and put more stress on the ones that are not regaining power so fast, in order to prevent any increase in imbalance.

At regular intervals, all patients should have a routine check-up by the surgeon, which should include the following points:

1. A complete reëxamination of muscle power, which is made at intervals of once a month for the first three or four months, and then every two months during the rest of the first year. An examination every four months is often enough for the older cases.

This examination will determine the choice of muscles to be strengthened by the physical therapy worker until the next examination, and will also control the decision of whether braces may be gradually discarded or should still be continued.

2. An inspection of the braces, at least every three or four months, to insure that the chronic cases who require them permanently have the necessary alterations and repairs to match their growth.

3. From these routine examinations, it can be determined whether the progress of the case is satisfactory in regard to muscle recovery, or whether a stationary period has been reached. If the latter, there should be a consideration of whether some operative procedure may now be of service, without further delay.

What Can Be Expected from Physical Therapy

It has been stated earlier that the greatest amount of spontaneous recovery of muscle power occurs during the second stage of poliomyelitis. This is the recovery following the absorption of the edema which had made pressure on some of the nerve centers of the spinal cord and temporarily interfered with their function, but had not destroyed them.

The greatest gain due to muscle training is made in the first nine months to a year of treatment. When the nerve centers controlling muscles are partially impaired, weakness or partial paralysis of those muscles is present. Such muscles will gradually gain in power by frequent repetition of active contraction of their muscle fibers, but

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will only make their maximum recovery when protected from such unfavorable conditions as fatigue, over-use, stretching, etc. On the other hand, if these muscles are not caused to contract by exercise, they will weaken from disuse, atrophy and gradually degenerate.

After the first year, weakened muscles will continue to gain under treatment, but their progress will be much slower than that of the uninvolved muscles which will gain at the normal rate. For this reason too, after-care should be carried on for many years after the onset, in order to guard against an increasing imbalance which may bring about late deformities. However, the actual gain made by the weakened muscles after the first year is of sufficient importance to warrant keeping up muscle training.

Just how much power can be regained, eventually, depends upon the amount of permanent injury which has been done to the nerve centers. If all the nerve centers controlling a muscle have been destroyed, there can be no return of power under any treatment, but the examiner is not justified in assuming this to be the case, on the strength of not obtaining any remnant of muscular contraction in the early examinations. A survey of 293 muscles which were rated totally gone on the initial examinations disclosed that two-thirds of these muscles showed some return of power after two years of treatment. When we group with the totally paralyzed muscles the next grade, consisting of muscles which sometimes show a remnant of response but are unable to produce any movement of the part to which they are attached, we find that 25 per cent, or one-fourth of a total of 694 muscles unable to produce any movement on the first examination, are able to function against gravity after two years of treatment.

Muscles which are able to produce some movement at the time of the initial examination, of course, show a greater proportion of gain. Of 6127 muscles able to produce some movement, 89 per cent were able to function against gravity two years later.

At the end of two years' treatment, a survey showed that 61 per cent of all the muscles in any degree affected had become normal.

Only 13 per cent of the muscles which were classified as "good" had not recovered to normal; 91 per cent of the "fair" muscles had reached good or normal; 58 per cent of the "poor" muscles had reached good or normal; and 21 per cent more had become "fair," that is, they were able to overcome gravity.

These statements give an idea of the actual gain in muscle strength which can be expected from treatment, but they do not show the additional value, to the individual patients, of the training which teaches them to utilize their assets. In other words, physical therapy also includes the reëducation which teaches them how to walk again, how to rise from chairs and handle themselves independently on stairs, as well as how to perform many of the other acts of normal life which represent the difference between an independent, though handicapped, individual, and a helpless cripple.

CHAPTER NINE

PHYSICAL THERAPY IN CEREBRAL SPASTIC PARALYSIS

EDWIN W. RYERSON, M.D.

Cerebral spastic paralysis, for the purposes of this paper, will be considered under three headings: (1) The Congenital Form in Children. (2) The Acquired Form in Children. (3) The Acquired Form in Adults.

THE CONGENITAL FORM IN CHILDREN

The congenital form is usually due to injury during the process of parturition, the skull being compressed during its passage through the birth canal, with a resulting intracranial hemorrhage from torn blood vessels. The extent of the hemorrhage and its location will determine whether the infant dies immediately or lives with a greater or lesser degree of damage to the cranial contents.

Routine lumbar punctures in more than nine hundred new-born babies showed blood in the spinal fluid in nearly 12 per cent, as reported by William Sharpe and Hines Roberts, but only a few showed any clinical signs of birth injury.

The hemorrhage is most often over the cerebrum and usually limited to one side, beneath the dura, but may be tentorial or from the large central veins.

Premature babies are especially liable to intracranial hemorrhage because of the thinness of the skull and the fragility of the blood vessels.

Hemorrhages of considerable size are apt to result in porencephalic cavities, which were formerly considered to be developmental defects. These are generally in the cortex and are due to tearing of tributary veins to the longitudinal sinus by the overlapping of the parietal bones as the head is compressed and molded during delivery.

The clinical signs of intracranial hemorrhage in infants are usually asphyxia and difficult resuscitation. The child is feeble, does not nurse and may be more or less comatose. There may be spasticity or convulsions. The fontanels may be tense or bulging. A lumbar puncture should always be made in doubtful cases, and if bloody spinal fluid is found, under increased pressure, the diagnosis is practically certain.

The most common form of congenital cerebral spastic paralysis is paraplegia, affecting both legs. It is usually called Little's disease and was described by him in 1862. When the arms are also involved, it is

known as diplegia. Hemiplegia is almost as common. Frank R. Ford, in his monograph published in 1927, states that true congenital cerebral diplegia is apparently not related to birth injury or to meningeal hemorrhage but is due to obscure developmental defects. The diplegias caused by injury or hemorrhage he prefers to call "bilateral hemiplegia."

The Acquired Form in Children

The acquired form of cerebral spastic paralysis in children is usually caused by infection, as from the middle ear or in the course of contagious diseases. Direct injury to an intracranial blood vessel is an infrequent cause. Spontaneous rupture of an artery, and thrombosis and embolism are rare in children but common in adults.

The Acquired Form in Adults

Adult spastic paralysis of the cerebral type usually occurs in persons past middle life, in whom a high blood pressure has existed for many years as a result of renal or cardiac disease. Infectious endocarditis predisposes to embolism, and syphilis is a frequent cause of thrombosis of the cerebral vessels. Rupture of a vessel in the brain, commonly called apoplexy, is perhaps more frequent than embolism and thrombosis. The resulting disability in all of these cases will depend upon the location and extent of the lesions. If death does not result immediately, or within a few days, the general tendency is toward improvement; in most cases a great deal of benefit can be afforded by the proper physiotherapeutic treatment.

Nearly all of the acquired spastic paralyses are unilateral and of the hemiplegic variety, affecting the arm and leg of the side opposite to the cerebral lesion.

The more unusual diseases which may cause intracranial lesions need not be detailed in a work of this kind, as the physical results and the physiotherapeutic treatment are practically identical with those mentioned before.

Treatment

In Children.—Considering first the ordinary cases of congenital cerebral spastic paraplegia, or Little's disease, it is of the greatest importance to determine the mental condition of the child before outlining the course of treatment. Children who are imbeciles or idiots can never become useful citizens, and it is a difficult social and economic problem to decide whether to improve their physical abilities or to leave them as they are. An idiot who is incapable of walking about may be less disadvantageous to a community than one who has full powers of locomotion. On grounds of common humanity, however, one might well hesitate to deny to any individual the help which medical science might afford. It is impossible, in some cases, to measure accu-

rately the mental capacity of very young children, and it is also true that medical or surgical treatment of the spastic disabilities sometimes produces considerable improvement in the mental status. For such reasons, then, public policy may dictate attempts to relieve even those who are severely handicapped.

In the absence of indications for cranial operations, the plan of treatment involves certain fundamental principles.

The clinical picture is that of an individual who has not, in the strict interpretation of the word, a true paralysis of any of his muscles. Every muscle in his body is intact and is capable of the normal range of contraction and relaxation, and the peripheral nerves, both motor and sensory, are undamaged. The motor centers in the cortex, however, have been compressed and irritated, or even destroyed, by the cortical injury and are no longer able to transmit properly the desired stimuli to the motor nerves. This results in a disarrangement in function of the muscles supplied by the damaged area of the cortex. Some of the muscles are overstimulated and contract too strongly. The opposing muscles are understimulated and fail to balance these strong contractions. The patient is unable to regulate voluntarily the unbalanced forces, and an incoördination of movement naturally results.

In the ordinary paraplegia of Little's disease, the large calf muscles, the gastrocnemius and the soleus, become overactive and pull too strongly upward upon the heel, producing the familiar equinus deformity of the foot. The child, therefore, walks upon the ball of the foot, with the heel raised above the floor. Similarly, the great hamstring muscles in the thigh overbalance the extensors and cause flexion of the knee. In most cases the three adductors of the thigh also act too strongly and draw the knees together so that they interfere with or even cross each other.

The treatment of this condition is carried out by frequent manipulation, several times daily, of the feet and legs; the knee, ankle and hip being put through the full normal range of motion and held in complete overcorrection for some minutes at a time. The resistance of the muscles can always be overcome by firm, steady pressure, which will cause no actual pain whatever, but which at first is often objected to by the patient. After the muscles have been relaxed and stretched by these manipulations, an attempt is made to have the child perform some voluntary movements of a simple nature, dorsiflexing the foot, extending the knee and abducting the thigh. Deep massage and kneading of the muscles may reduce their spasticity but must be done slowly and firmly, because rapid and light tapping massage tends to increase, rather than to decrease, muscular irritability.

No form of electrical stimulation should ever be used in any variety of spastic paralysis. Galvanism and faradism, therefore, are absolutely contraindicated.

No alternations of heat and cold, as for example, "contrast baths," should be used.

known as diplegia. Hemiplegia is almost as common. Frank R. Ford, in his monograph published in 1927, states that true congenital cerebral diplegia is apparently not related to birth injury or to meningeal hemorrhage but is due to obscure developmental defects. The diplegias caused by injury or hemorrhage he prefers to call "bilateral hemiplegia."

The Acquired Form in Children

The acquired form of cerebral spastic paralysis in children is usually caused by infection, as from the middle ear or in the course of contagious diseases. Direct injury to an intracranial blood vessel is an infrequent cause. Spontaneous rupture of an artery, and thrombosis and embolism are rare in children but common in adults.

The Acquired Form in Adults

Adult spastic paralysis of the cerebral type usually occurs in persons past middle life, in whom a high blood pressure has existed for many years as a result of renal or cardiac disease. Infectious endocarditis predisposes to embolism, and syphilis is a frequent cause of thrombosis of the cerebral vessels. Rupture of a vessel in the brain, commonly called apoplexy, is perhaps more frequent than embolism and thrombosis. The resulting disability in all of these cases will depend upon the location and extent of the lesions. If death does not result immediately, or within a few days, the general tendency is toward improvement; in most cases a great deal of benefit can be afforded by the proper physiotherapeutic treatment.

Nearly all of the acquired spastic paralyses are unilateral and of the hemiplegic variety, affecting the arm and leg of the side opposite to the cerebral lesion.

The more unusual diseases which may cause intracranial lesions need not be detailed in a work of this kind, as the physical results and the physiotherapeutic treatment are practically identical with those mentioned before.

Treatment

In Children.—Considering first the ordinary cases of congenital cerebral spastic paraplegia, or Little's disease, it is of the greatest importance to determine the mental condition of the child before outlining the course of treatment. Children who are imbeciles or idiots can never become useful citizens, and it is a difficult social and economic problem to decide whether to improve their physical abilities or to leave them as they are. An idiot who is incapable of walking about may be less disadvantageous to a community than one who has full powers of locomotion. On grounds of common humanity, however, one might well hesitate to deny to any individual the help which medical science might afford. It is impossible, in some cases, to measure accu-

After these operations, the legs and feet are encased in a double plaster-of-paris spica, with the knees straight, the feet in the neutral right-angled position and the legs widely abducted. In six weeks or less the spica is removed, and physical therapy is again instituted.

The Hand.—In cases of hemiplegia, the hand and arm may be seriously disabled, and the problem of restoring function here is much more difficult than in the legs and feet because of the more highly differentiated character of the demands upon the upper extremity. The elbow and wrist are usually flexed, and the hand is apt to be deviated to the ulnar side, with marked adduction of the thumb. Voluntary attempts by the patient to perform movements with the hand or fingers cause incoördinated contractions of the muscles, so that proper function is impossible. A long course of faithful physical therapy and muscle-training must be persisted in, and in some cases the results are very satisfactory. It is of great benefit to tie the normal hand and arm behind the back, so that the child is obliged to use the spastic hand for all purposes of work or play. It is often difficult to obtain the coöperation of the parents in this procedure because of their undue sympathy with the struggles of the child to escape from the bondage. The hand should be incased in a long mitten or bag, made of strong cloth or leather, which is laced or tied to the wrist or above the elbow and is in turn fastened securely to the waistband in the back. When this can be conscientiously carried out, it is the most successful method known to the author.

In spite of all possible conservative measures of treatment and education, there will remain a rather high proportion of patients who will not obtain sufficiently good function. For these, considerable benefit may result from well-planned and well-executed operative procedures. The flexors of the wrist, namely, the flexores carpi radialis and ulnaris, may be lengthened by open division. When pronation of the hand is extreme, the pronator radii teres may be divided or may be transplanted behind the radius so as to act as a supinator, as in A. H. Tubby's operation. It may also be necessary to cut the pronator quadratus, just above the wrist joint, on the palmar side.

The adducted position of the thumb, due largely to overaction of the opponens pollicis, is difficult to remedy. Simple division of this muscle is not usually satisfactory. It is probably better to cut the small branch of the median nerve which supplies this muscle, the incision being made at the base of the thenar eminence.

Undue flexion of the fingers is another stumbling-block. If the flexor tendons be lengthened by open operation, the result is apt to be vitiated by a mass of adhesions, all of the tendons becoming matted together with no possibility of individual action. In a few cases, the tendon of origin of the flexors has been detached from the condyle of the humerus, with considerable benefit. This, of course, lengthens only the long head of the flexor sublimis, but the dissection can be carried down to include the ulnar head of the flexor profundus. Both of these muscles

Braces, splints, and plaster-of-paris casts are of little use in cerebral spastic paralysis. They do not prevent contraction of the muscles, nor do they aid in locomotion. Their only field of usefulness is to immobilize the extremities for a suitable time after operative procedures have been instituted, as will be described later in this article.

The dominating factors of the conservative treatment are, first, to make the muscles flexible and relaxed by stretching and kneading and then to teach the patient to use the muscles in the proper manner. Success can only be attained by constant effort and inexhaustible patience on the part of the attendant. Instruction carried out in classes is very valuable, as the stimulus of competition and association with other similarly afflicted children leads to more rapid improvement. This is well exemplified at the Spaulding School for Crippled Children in Chicago, where for some years a special department for spastics has been conducted with great success.

Later Treatment.—Faithful perseverance in the conservative treatment should be continued for many months. If it then becomes evident that the spasticity is too great to respond to the simpler measures, operative interference should be considered.

There are two distinct methods of operation which have stood the test of time:

1. Lengthening of tendons and muscles.
2. Reduction of nerve supply to the spastic muscles (Stoffel's operation).

Neither method produces perfect results in any case. Both methods lessen the spasticity very materially. Tendon lengthening is easier and is not destructive. If too great lengthening should occur, the tendon can readily be shortened. Stoffel's operation is difficult and technical, in comparison; if too much of the nerve supply is cut off, the damage cannot be repaired.

A combination of the two methods is often more successful than the use of either alone.

In the writer's clinic, the ordinary procedure is as follows: Under general anesthesia the Achilles tendons are lengthened one-half to three-quarters of an inch by the open plastic method. The biceps, semitendinosus and semimembranosus tendons are then exposed by incisions on both sides of the popliteal space and are cut across completely, being allowed to retract as far as they may. The child is then turned over on the back, and the obturator nerves are exposed by a short incision downward from the spine of the pubis. The fascia is separated, exposing the adductor brevis and the adductor longus. Between these muscles the two branches of the nerve are easily found. In mild cases only the anterior branch need be divided. In severe cases both branches are cut, and some operators remove a half inch or more of the nerves.

readily be lengthened by operations performed under local anesthesia, with a minimum of risk and, in many instances, with brilliant results.

It will be noted that no mention has been made of Royle and Hunter's sympathetic ramisectomy, nor of Förster's division of the sensory nerve roots. The writer feels that the ramisectomy is still of somewhat doubtful value, and that Förster's operation should definitely be abandoned.

To sum up the views presented in this article, the cardinal principles of treatment in cerebral spastic paralysis embrace:

1. Early and long-continued training in the proper use of the affected extremities, thus strengthening the weaker muscles.

2. Conservative efforts to reduce the spasticity by massage, manipulations and stretching.

3. Diminution of the power of the overstimulated muscles by lengthening their tendons (thus shortening their range of contractility) or by reducing their nerve supply.

lie beneath the flexores carpi radialis and ulnaris, the palmaris longus and the pronator radii teres, all of which can be, and in fact must be, detached at the same time. The entire arm, forearm and hand are then placed in a plaster-of-paris splint, with the elbow in full extension, the wrist hyperextended and the hand supinated, for a period of five weeks. The educational and physical therapeutic treatment is then resumed.

As an alternative to the operation of lengthening the muscles and tendons, the selective nerve-division operations of Stoffel may be used. The nerves supplying the spastic muscles are exposed, and one or more of the fibers running into the muscle bundles are cut across, or a section of them is removed. This paralyzes a corresponding portion of the muscle, greater or lesser as the surgeon deems advisable. The results in many of these cases are excellent. The writer has not used this method as freely as have some of his confrères, because the operation is essentially a destructive one and its effects cannot be modified in case too many nerve fibers have been divided. It is also a somewhat inaccurate procedure, since it is impossible to determine precisely how much of the nerve supply to sacrifice in any individual instance. When a muscle or tendon has been lengthened too greatly, it is easy to shorten it the requisite amount, but when a small motor nerve has been sectioned, it is practically impossible to repair it. The Stoffel operation, nevertheless, is of great value when judiciously utilized in suitable cases, especially in the adductors of the thighs, the flexors of the fingers and the opponens pollicis.

In Adults.—Cerebral spastic paralysis in adults, as a result of hemorrhage, embolism or thrombosis, usually occurs suddenly, with profound constitutional disturbance. Treatment of the peripheral disability must be deferred until the general condition is satisfactory. The hemiplegia tends to improve rapidly at first, and then more slowly. In many cases the medical attendant fails to appreciate the value of physical therapy in the treatment of individuals who have suffered a "stroke," and these unfortunates are allowed to drift along with a crippled hand and arm which might be made comparatively useful by proper therapy.

The plan of treatment advised for hemiplegia in children is applicable also to adults. Their coöperation is more easily secured in the physiotherapeutic measures, but, as many of them are advanced in years and are often not good operative risks, it is not so frequently advisable to perform operations. Muscle-training is of great value in adults and is best carried out by rhythmical motions of both hands or both legs at the same time; that is, symmetrical, synchronous movements rather than the use of only the extremity involved. Persistence in the training will often result in unexpectedly good function.

In cases of disabling contractions or contractures of the calf muscles or the hamstrings, it must be remembered that these tendons can

CHAPTER TEN

THE PHYSICAL THERAPY OF OBSTETRICAL PARALYSIS

James Warren Sever, M.D.

Obstetrical paralysis was first described by Smellie in 1768, but was brought to the attention of the medical profession in 1872 by Duchenne, who described four cases.

The paralysis is due to the tearing of the cords of the brachial plexus as a result of forcible separation of the head and shoulder at birth. This has been confirmed by operation, by autopsy, and by clinical observation. The resultant paralysis is characteristic. The arm hangs limp at the side, with the elbow extended, the forearm pronated, and the whole arm inwardly rotated. The paralysis is always flaccid.

It has been conceded by practically all observers that a difficult labor is a predisposing factor in the cause of this paralysis. The labor is usually long and difficult, and ether or forceps are used (Fig. 1). All the conditions noted above imply the application of force, combined with great muscular relaxation of the child—conditions peculiarly favorable for the production of such an injury. A moderately large number have had the head delivered naturally, but the "shoulder stuck," and at that time force was applied.

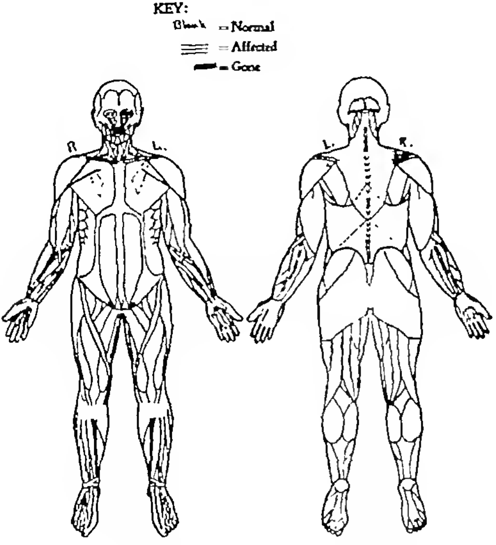
The presentations are generally vertex or of the face variety, and about a quarter breech, the latter classification including versions and footlings (Fig. 2).

The condition of unequal pupils is probably overlooked in some cases, and is a most important symptom in that it means definite injury to the two lower cords of the plexus and the first thoracic nerve which have communicating bands with the cervical sympathetic, or injury in the spinal cord itself. The prognosis in these cases is usually not so good as in those which do not show this sign.

Types of Paralysis

There are generally recognized two distinct types of paralyses. The more common consists of a lesion which involves the fifth and sixth cervical roots and the suprascapular nerve, and produces a paralysis of only the muscles of the upper arm, with the exception of the

and possibly the first thoracic as well. Here the whole arm is flaccid, there is a wrist drop and there is paralysis of the small muscles of the hand (Figs. 8, 9). There occurs also, although rarely, the pure lower arm type of paralysis, in which there is no involvement of the upper cords of the plexus, the so-called "Klumpke's" paralysis. In these whole



FIGS. 4, 5—Chart showing typical upper arm type of obstetrical paralysis.

arm cases the paralysis is usually the result of stretching the plexus (Figs. 10, 11) from overextension of the arm in head presentation, and of injury to the lower cords of the plexus, namely, the seventh and eighth cervical and the first dorsal roots. The paralysis may at times be bilateral. It is in this type that one often sees inequality of pupils,

supinators. This is known as the "upper arm type," the so-called Erb's paralysis (Figs. 3, 4, 5). The less usual variety, the so-called "lower arm" or "whole arm" type (Figs. 6, 7), is the result of injury not only to the fifth and sixth cervical roots, but to the seventh and eighth

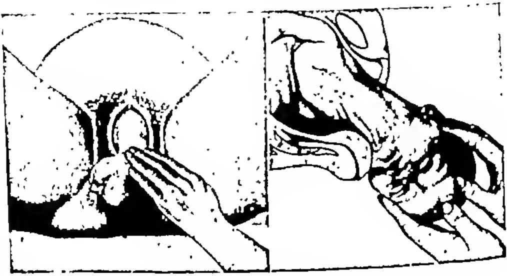


FIG. 1—Separation of head and shoulder, with shoulder caught behind the pubes (Nagel.)
FIG. 2—Stretching of nerves by oblique traction when the shoulder is caught under the pubes.

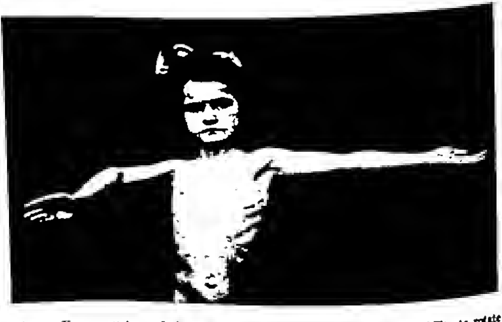


FIG. 3—Upper arm type of obstetrical paralysis before operation. Note inability to rotate arm outwardly, to abduct, and to supinate. Note flexion at elbow.

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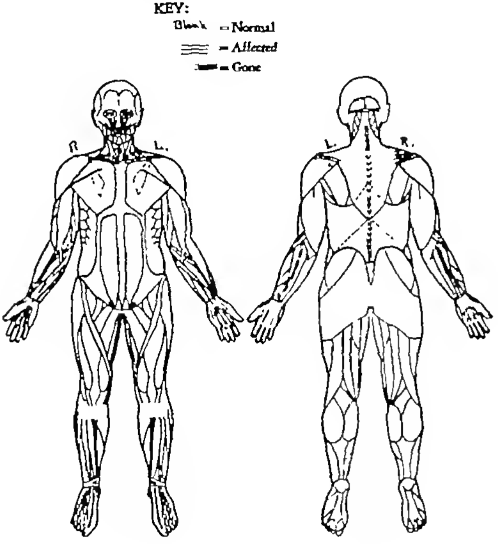

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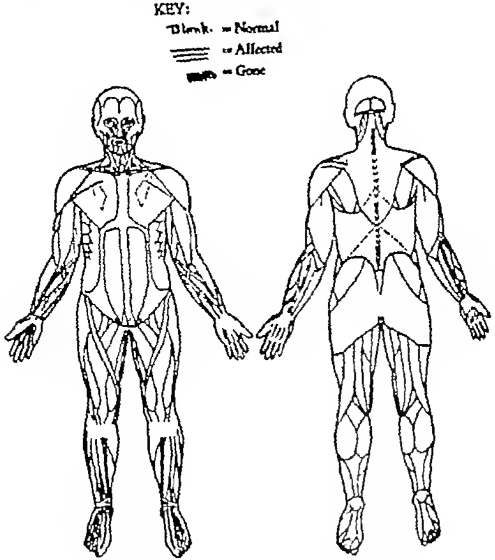
owing to the fact that the sympathetic fibers from the deep cervical ganglionic plexus enter the spinal cord through the first thoracic and at times through the eighth cervical roots. Injury, therefore, to these roots leads to an uncontrolled stimulation of the motor oculi nerve.



FIGS. 6, 7—Typical lower or whole arm type of obstetrical paralysis.

CONDITIONS RESULTING FROM IMPAIRMENT OF FUNCTION

Pathologically, in the milder cases, the stretching or tearing results in a greater or lesser degree of hemorrhage or edema into the nerve sheaths. In others there may be a rupture of the perineural sheath, accompanied by hemorrhage into the substance of the nerve trunk, associated with a tearing apart or a separation of the nerve fibers.

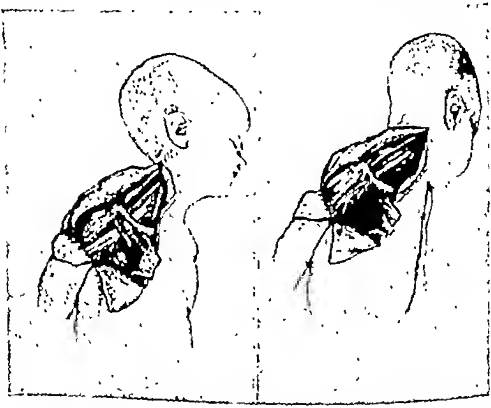
This latter condition leads, of course, to a permanent impairment of function, and the formation of scar tissue in the nerve tract. In the more severe cases of the upper arm type there is a partial or complete division of the fifth and sixth cervical roots which leads to a more permanent form of paralysis than usual, and the formation of a more extensive area of scar tissue.

FIGS. 8, 9.—Lower arm type of obstetrical paralysis, showing right arm held in extreme internal rotation in attempted elevation, a characteristic position.

It has been shown that traction and the forcible separation of the head and shoulder put the upper cords, the fifth and sixth cervical roots of the brachial plexus, under dangerous tension. This tension is so great that the two upper cords stand out like violin strings. Any sudden force applied with the head bent to the side and the shoulder held would, without question, injure these cords. It has also been

shown that forcible abduction and elevation of the arm and shoulder put the lower cords of the plexus, the eighth cervical and first thoracic, on a stretch, and the application of much force may well lead to a tear, rupture, or other injury to these segments. This condition is seen in breech cases, with arms extended. It may also follow sudden strain when the arm is elevated, such as the so-called "hostler's paralysis," caused by the sudden elevation and strain of the arm which occurs when a hostler holds a rearing horse.

When the shoulder is held and the head is carried to one side, with the clavicle intact, considerable force is necessary to injure the



FIGS. 10, 11.—Diagram of brachial plexus. FIG. 10, head and shoulder in normal relation to each other. The plexus is not on the stretch. FIG. 11, head and shoulder forcibly separated; note the stretched position of the plexus, particularly the three upper roots.

plexus. The suprascapular nerve always gives way first, apparently because it has not so much freedom of play as the others. A fractured clavicle, of course, allows the weight of the shoulder to drag on the plexus and so predisposes to greater injury from traction. Rotation of the head combined with forcible abduction apparently does not greatly increase the degree of tension on the plexus and certainly not enough to cause additional damage. Most birth fractures occur in the

clavicle, or in the humerus, at about the junction of its upper and middle thirds.

At birth, the shaft of the humerus is nearly wholly ossified, but the two extremities are cartilaginous. The scapula at birth is largely osseous, with the exception of the glenoid fossa, the coracoid and acromial processes, and the posterior border and inferior angle, which are still cartilaginous. It is on account of these conditions that fractures in these regions, at birth, are practically nonexistent. It is not possible to produce a paralysis of the Erb type by the fracture of any bone but the clavicle, and then the paralysis is due to the plexus injury itself, and not alone to the fracture (Fig. 12).

Conditions Shown by X-Rays.—A study of roentgenograms taken in cases of obstetrical paralysis shows the following conditions:

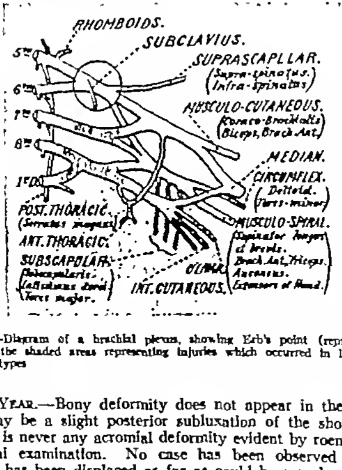


Fig. 13.—Diagram of a brachial plexus, showing Erb's point (represented by a circle) and the shaded areas representing injuries which occurred in lower arm, or whole arm, types

First Year.—Bony deformity does not appear in the first year. There may be a slight posterior subluxation of the shoulder joint, but there is never any acromial deformity evident by roentgenograms or clinical examination. No case has been observed where the epiphysis has been displaced as far as could be seen by comparison with the normal shoulder. The epiphysis, as well as the shaft of the humerus, is always smaller than the unaffected side, a condition which is undoubtedly due to atrophy from disuse. The scapula is practically

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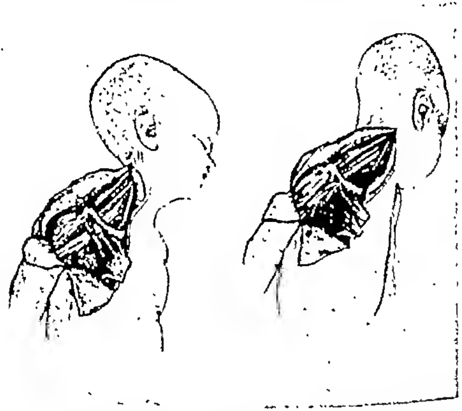

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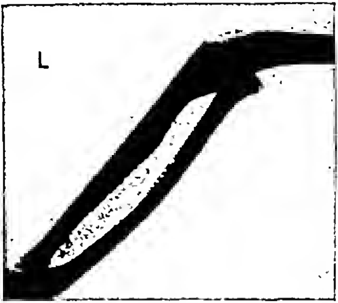

Fig. 14—X-ray of case of obstetrical paralysis, showing secondary deformity resulting from dislocation of head of radius.

Fig. 15—Typical upper arm type of obstetrical paralysis. Note inability to elevate, abduct, outwardly rotate, and supinate hand and arm

always elevated and outwardly rotated, due apparently to the pull of the intact inward rotators and the levator anguli scapulae.

LATER YEARS.—As time goes on and the child gets older, one begins to see increasing evidence of bony deformity, occasionally more joint subluxation than at first, increasing outward displacement and elevation of the scapula, and acromial deformity. The deformity of the

FIG. 13—X-ray showing bony deformity of the shoulder joint in a case of obstetrical paralysis of the upper arm type, marked hooking or elongation of the acromion, marked elongation of the coracoid process, and posterior subluxation of the head of the humerus. At operation both these bony obstructions had to be removed before the subluxation could be reduced

acromion consists of a bending downward and forward, or a hooking, of its outer end, which, apparently having no bony resistance to meet as normally in the head of the humerus, projects downward in front of the posteriorly subluxated and inwardly rotated head (Fig. 13). This hooking seems to vary directly with the degree of posterior subluxation and inward rotation of the humerus, and tends to increase as the child gets older, provided subluxation is present.

of the upper arm type: The arm lies limp at the side, is extended, and is inwardly rotated with complete inability to abduct, elevate, ontwardly rotate, or supinate (Fig. 15). The muscles paralyzed in the typical upper arm type are as follows: deltoid, supraspinatus, infraspinatus, teres minor, biceps and supinator fongus, and occasionally the serratus magnus, coracobrachialis and supinator longus. The arm cannot actually be flexed at the elbow, but as a rule the lower arm is not affected so far as flexion and extension of the fingers go.

Shoulder.—The inability to raise or abduct the arm at the shoulder is due to the paralysis of the deltoid and supraspinatus. Outward rotation cannot be accomplished because of the paralysis of the infraspinatus and teres minor, and the arm cannot be internally rotated because the internal rotators—namely, the teres major, the subscapularis, and the latissimus dorsi—are already fully contracted due to lack of opposition (Figs. 16, 17).

Elbow.—The arm cannot be flexed at the elbow owing to the paralysis or weakness of the biceps, brachialis anticus, coracobrachialis and supinator longus, and supination cannot be carried out because of the inward rotation in which the arm is held, and the weakness or paralysis of the biceps and supinator longus or brevis.

Sensation.—In regard to sensation, it may be stated that it has been impossible in early cases to determine any changes from the normal on account of the age of the patient. During the first week in early cases, the child may cry if the arm is handled or moved, especially in abduction, but this soon disappears. In one or two cases some swelling and tenderness have been noted by palpation over the plexus above the clavicle. This condition, however, apparently has no connection with the degree of paralysis present. The hand grip is usually good, and the child flexes and extends the wrist and fingers well.

Later Developments.—The later developments in the upper arm cases, as the child grows older and develops, with or without exercises and massage, are as follows: The persistence of the inward rotation and adduction deformity; the so-called "policemen's tip" position; the inability in most cases to supinate fully or freely; the inability to get the hand to the mouth, without raising the elbow, due to inability to rotate outwardly; and the inability to put the hand to the head or behind the back.

Typical Lower Arm Conditions.—In the lower arm type, all these conditions hold besides the additional ones due to the paralytic conditions of the lower arm and hand, resulting generally in a useless dangling arm (Fig. 18).

Deformity at Elbow.—Contraction of the biceps and brachialis anticus always leads to some degree of permanent flexion deformity at the elbow, and not rarely to a subluxation or even a complete dislocation of the head of the radius (Fig. 14). Persistence of marked loss of power in the triceps is not uncommon and may be a factor in causing this condition.

Roentgenograms of the elbow practically never show any bony change of importance.

It has been suggested that the flexion deformity is due to the consequent change in shape or depth of the olecranon fossa, which conse-

Figs. 16, 17—Picture showing elongation of the acromion on the affected side.

quently acts as a bony block to full and free extension. This is not so; the limitation is wholly due to contraction of the anterior elbow muscles and can be corrected only by a subperiosteal lengthening of their structures, as well as by a lengthening of the biceps tendon. Gradual stretching in a cast or turnbuckle splint might occasionally accomplish the same thing.

Typical Upper Arm Conditions.—When the child is first seen, if within a few days or weeks after birth, the following picture is classical

or adduction of the hand. These cases, almost without exception, *represent severe tearing* injuries to the roots of the plexus, and although some of the muscles may recover in part, particularly the upper arm and shoulder groups, the lower arm cases practically never recover, even after attempted operative repair of the plexus. It is in these cases that sensation is more apt to be impaired than in the usual upper arm type.

FIG. 19—Plaster cast to hold arm abducted, elevated, outwardly rotated and supinated.

TREATMENT

First of all, *the use of electricity plays no part in the treatment of these cases.* All kinds have been tried and all have been given up as wasteful of time and effort.

Atrophy.—Atrophy of the muscles in these cases of obstetrical paralysis is never very marked except in some cases of the lower arm type. One never sees the extreme atrophy so noticeable in cases of infantile paralysis. This lack of marked atrophy is undoubtedly due to the fact that the nerve impulses are rarely fully blocked; thus the muscles practically never, except in rare cases, wholly lose their entire innervations. Some normal nerve impulses pass through the scar tissue at the site of the lesion, owing to incomplete destruction or injury of the nerve, and so keep the muscle tone up to a certain point. There is always a definite shortening of the arm in all cases, however, due probably as much to nerve injury as to lack of use.

Nerve Involvement.—In the classification of the whole arm or lower arm type are placed those cases which show any nerve involve-

FIG. 18—Typical case of lower arm type of obstetrical paralysis. Note paralysis and contracture of hand.

ment beyond that usually shown by an injury of the fifth and sixth cervical roots. Pupillary inequality and narrowing of the palpebral fissure are not unusual with this type. Wrist drop is the usual condition associated with the usual inability to supinate, and the additional inability to extend the lower arm. Paralysis of the flexors and extensors of the wrist and fingers is common, associated with paralysis and atrophy of the intrinsic muscles of the hand. Often the proximal phalanges are hyperextended, and the *distal* ones flexed, due to the paralysis of the interossei or lumbricales muscles. There is, of course, no power to grip and the fingers cannot be moved. There is usually ulnar displacement

FIG. 10—For flexion of fingers and arm action. "Here's a ball for baby, big and soft and round."

FIGS. 11, 12—For the supinators alone, showing the two active exercises.

The treatment at once resolves itself into two divisions: i.e., those to be treated with massage and exercises, principally those of the upper arm type; and those to be treated by operation on the plexus, usually those of the lower arm type. Unless the early treatment has been adequate, the upper arm type will also come to operation, not to repair the plexus, but to correct contraction deformities. This operation, which has been devised by the author, will be discussed later.

At first, in order to prevent contraction of unparalyzed muscles, it is best to put the arm at rest in a position where such muscles cannot become contracted. This may be done by holding the arm in a plaster cast (Fig. 19), or by using a light wire splint, in an abducted, elevated and outwardly rotated position, with the hand supinated. This position should be maintained between massage and gymnastic treatment, because it insures a better subsequent position of the arm. It also takes the drag off the paralyzed muscles, allowing them to regain their strength more quickly, and prevents subsequent shoulder joint deformity, such as subluxation and acromial hooking.

Massage and Exercises.—Massage and exercises are of the greatest importance and should be carried out daily if possible. It is most unwise to allow a child to become obsessed with the idea that it has an arm which cannot be used. The mother is instructed to dress the paralyzed arm first but to undress it last. She is told that each time she takes up the baby, for nursing or other reasons, she should straighten out the fingers and wrist and supinate the forearm, as shown. Later she is shown how to abduct, outwardly rotate, and elevate the arm. One has to be guided by the intelligence and adaptability of the mother as to when it is wise to allow her to perform these motions. A very good rule to give her is that she is not to do anything with the affected arm that she does not see the well arm do.

Passive and Active Exercises.—The rhythm of exercise is of utmost importance. One will find the singing of nursery rhymes while conducting the exercises advantageous in developing rhythm and in preventing the child from tiring of the exercise. Any suitable rhyme may be used, but must be sung with life and enthusiasm so as to impress upon the baby the association of the song or rhyme and the movement. It is surprising how early the child learns the association of ideas.

As an example of this method, take the flexion and extension exercises for the fingers (Fig. 20). It is natural for a baby to play with its fingers, so impress upon the child from the beginning that it has two hands.

Motions for Upper Extremity.—The child is laid on its back on a padded table and the arm or arms undressed. Beginning with the fingers and working up the arm and over the scapula, massage is

Fig. 20—For flexion of fingers and arm action. "Here's a ball for baby, big and soft and round."

Figs. 21, 22—For the supinators alone, showing the two active exercises.

given to increase the circulation and nutrition. Then each finger and thumb, first separately and then collectively, is extended and flexed, at the same time some kindergarten or nursery song is sung, such as:

This is little Tommy Thumb,
Round and fat as any plum.
This is little Peter Pointer (index),
Surely he's a double jointer.
This is little Toby Tail (middle finger),
He's the biggest one of all.
This is little Ruby Ring (fourth finger),
She's too fine for anything.
And the little wee one, Maybe (fifth finger),
Is the little finger baby.

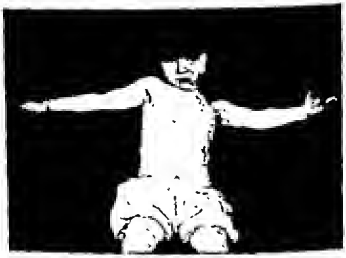

FIG. 13—For abduction at shoulder (with palms turned up, arm extended sideways)

Then collectively:

The little birdies in their nest
Go hop, hop, hop, hop, hop.
They try to do their very best
And hop, hop, hop, hop, hop.

This is just an example of flexion and extension exercises for the fingers. To train the extensors of the wrist we sing:

This way, that way, blows the weather vane,
This way, that way, blows and blows again,
Turning, pointing, ever showing,
How the merry wind is blowing.

The emphasis is, of course, always put on the motion necessary to train the weaker muscle.

FIG. 14—Elevation of arm; starting position for "Yards of ribbon" and "Ready, rockets."

FIG. 15—Elevation of arm: "Ready, Shoot fast."

FIG. 16—For elevation and abduction of all shoulder group muscles. This is the same as arms upward stretch: "Shoot."

For the supinators (Figs. 21, 22), sing:

Roll over, roll over, so merry and free,
My playfellows dear, come join in my glee.

Try to have the child meanwhile actively supinate, assisted, of course, if necessary.

FIG. 27—For abduction at shoulder: "Pump the water," etc.

For flexion and extension at the elbow to exercise the biceps and triceps, sing:

Up, down, up, down,
This is the way we go to town,
What to buy? To buy a fat pig,
Home again, home again, rig-a-gig-gig.

Of course, at first, and for a long time, one must not only actively assist the child with these exercises but must also perform them while the child is passive.

For abduction at shoulder, the position shown by Figure 23 is used, except that the forearm is supinated. With the exercises, sing:

> One yard of ribbon,
> Two yards of ribbon,
> Three yards, four yards,
> And tie a big bow on your hair.

elevation of arm (Figs. 24, 25, 26), sing:

> Ready, rockets! Shoot!

Repeat six or eight times. This is the same as arms upward stretch. Starting with the arms bent or flexed at elbow, stretch straight above head with palms facing each other. This is for exercise of all shoulder group muscles concerned in elevation and abduction.

For abduction at shoulder, hold the arm externally rotated, semi-flexed at the elbow, with forearm supinated. Bringing it to full abduction and then to body, somewhat after the manner in which the old-fashioned pump worked (Fig. 27), sing:

> Pump the water, pump the water,
> Pump, pump, pump.

The exercises for the upper arm and shoulder may be carried out with the child lying on its back; or if an older child, it may sit up with its back against a straight chair or wall. The scapula should always be controlled by direct hand fixation.

For external rotation hold the forearm flexed at right angles, with forearm supinated and upper arm close to the body of the child (Fig. 28). Then carry it back till the thumb touches the table (Fig. 29), and returning to starting position, describing a semicircle downward (Fig. 30), sing:

> Grind the coffee, grind the coffee,
> Grind, grind, grind.

While circumducting the arm, sing:

> Crank the auto (up),
> Crank, crank, crank.

This exercise stretches the adductors and internal rotators at the shoulder.

This covers all the motions of the upper extremity. Each case requires special emphasis on different motions. This rests with the

For the supinators (Figs. 21, 22), sing:

Roll over, roll over, so merry and free,
My playfellows dear, come join in my glee.

Try to have the child meanwhile actively supinate, assisted, of course, if necessary.

FIG. 17—For abduction at shoulder: "Pump the water," etc.

For flexion and extension at the elbow to exercise the biceps and triceps, sing:

Up, down, up, down,
This is the way we go to town,
What to buy? To buy a fat pig,
Home again, home again, rig-a-gig-gig.

condition of the arm, and must be left to the operator's judgment, or the doctor's prescription for treatment.

When one finds a contracted pectoral, subscapularis, or teres major, one must be sure to fix the scapula while elevating and externally rotating the humerus. A contracted pectoral in a baby may be overcome by faithful treatment. The older babies and children seen (one to twelve years) usually have contractures of the pectoral, subscapularis, and teres major, and occasionally of the pronator radii teres. These cases, in addition to the treatment described, are put up in a wire splint, which fits over the pelvis and holds the arm in position of external rotation, semiflexion and supination. These children should be given the exercise of hanging on stall bars, or a trapeze.

Whole or Lower Arm.—In the whole or lower arm type, it is advisable to give three months' treatment, and if the fingers do not then show a tendency to recover, it may be well to explore the brachial plexus and repair the nerves if possible. These cases are most discouraging. No improvement is hoped for before a year. I have seen a few of these babies begin to have the slightest amount of flexion of the fingers in from six to twelve months, and very slowly improve. By the end of the third year, they are beginning to build blocks. It is the feeling of nearly all the medical profession that it is useless to do any nerve surgery in these cases. When these children begin to get motion in their fingers, they are taught to build with blocks (using colored blocks two inches square), put large colored pegs in a pegboard, and string beads (the large colored kindergarten beads). A child suffering from upper arm obstetrical paralysis can be taught to build blocks as early as five or six months, provided its training has been started early. After the exercises, the child is again given the arm massage to rest the muscles.

Children naturally are imitators and live in the land of make-believe. If the operator, when treating a child between two and six years, has sufficient sympathy with him, she will find him of the greatest help in improvising games. All she will have to do is to direct the execution of the movements so as to bring into play the muscles which she wishes to develop. When treatment has not been started until after the child is a year and a half old, the first thing the operator must do is to gain its confidence. Once this is accomplished, there is pretty clear sailing. She should never deceive a child. With tact, sufficient patience, and sympathy, she can get it to try everything, and to allow her to exert considerable strength in stretching contractures.

The treatment should be continued for several years at least, and if contractures develop in the subscapularis and pectoralis major, they must be divided before any further range of action in the arm is to be hoped for.

Author's Operation.—Technic.—An incision is made on the anterior aspect of the arm, beginning at the tip of the acromion and

FIGS. 28, 29, 30—Three exercises for external rotation of forearm as well as supination of hand.

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Author's Operation.—Technic.—An incision is made on the anterior aspect of the arm, beginning at the tip of the acromion and

carried down to below the insertion of the pectoralis major (Fig. 31). The cephalic vein is found generally in the outer edge of the wound and tied or drawn aside. The tendinous insertion of the pectoralis major is defined, raised on an instrument, and divided all the way across. The pectoralis major muscle is then retracted inward out of the way, giving one a clear view of the axilla and shoulder joint. The arm should now be abducted fully and rotated outward as far as possible.

Following the division of the pectoralis major, the range of motion in abduction will be greatly increased. Outward rotation will, however,

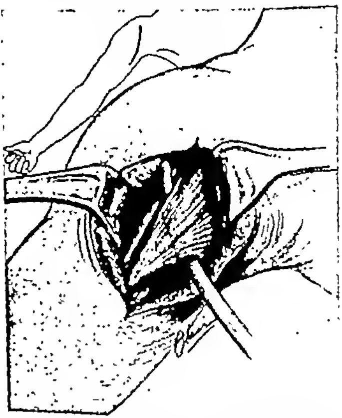

FIG. 31—Skin incision and isolation of pectoralis major. Cephalic vein at outer edge of pectoral. Arm abducted and rotated out. Insert shows position of arm and line of incision.

be somewhat limited. With the arm fully abducted and outwardly rotated, the insertion of the tendon of the coracobrachialis is to be defined. This tendon is inserted on the coracoid process of the scapula. The tendon of the coracobrachialis obscures the insertion of the subscapularis. It is, therefore, necessary to separate the origin of the coracobrachialis from the coracoid process, which in older children is generally much elongated, by means of an osteotomy. This allows the coracobrachialis to slide downward out of the way and gives one

a much clearer field to see the insertion of the subscapularis, which then comes into view. Just below this latter tendon are always found two or three small veins running parallel to the lower edge.

The best way to divide the tendon is to pass under it some blunt instrument and so define it. It is of the utmost importance that the shoulder joint should not be opened (Fig. 32). The tendon of the subscapularis should always be identified and lifted up before it is divided. Blind cuts along the capsule do more harm than good and should never be made. Following the division of the subscapularis the

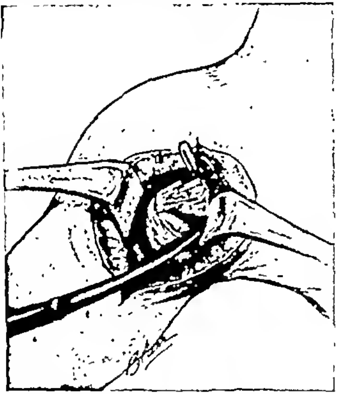

FIG 32—Sound under subscapular tendon. The pectoralis major has been divided. The joint capsule shows at bottom of cavity.

outward rotation and the abduction are entirely free. If at this stage there is still some subluxation of the head of the humerus which cannot be fully reduced, an osteotomy of the acromion should be performed and the loose distal piece either removed or tilted up to allow the head of the humerus to slip back into the glenoid. The wound is then closed with a few stitches uniting the fascia, and a silk stitch through the skin. No drainage is required. Usually very little bleeding takes place. The arm is then placed on a wire splint, which holds it elevated to or above the shoulder level, abducted, and fully rotated outwardly with the hand in full supination (Figs. 33, 34).

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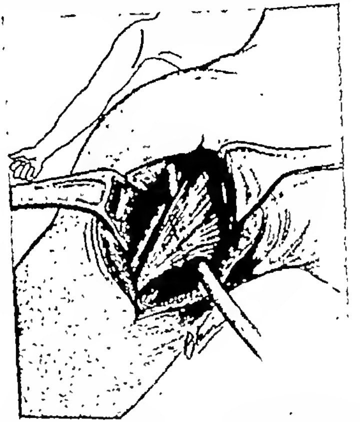

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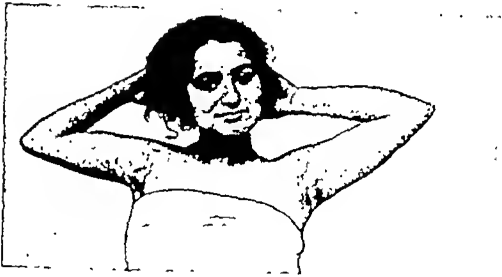
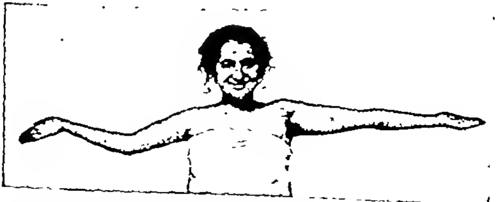
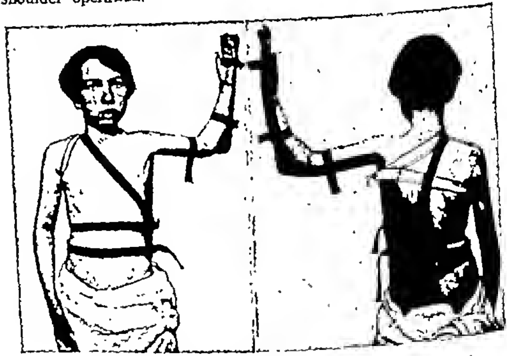




Figs. 35, 36, 37—Obstetrical paralysis of *right* arm, upper arm type, showing inability to abduct, outwardly rotate, and supinate. Fig. 35, before operation; Fig. 36, after operation. Note ability to put hand to the head easily. Fig. 37, one year after operation: free abduction, outward rotation and supination.

At the end of ten days' massage, baking and exercises are begun, and are continued daily, or at least four times a week. The splint should be worn night and day for at least three months.

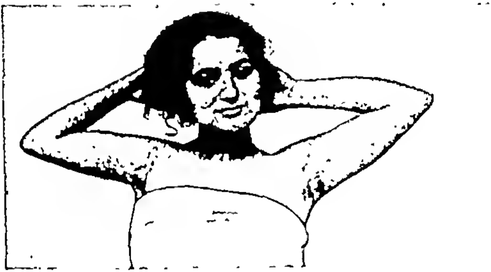
The operation merely releases contractions, giving the stretched and partly paralyzed muscles a chance to recover their tone and strength, and consequently the after-treatment is of the utmost importance. In a certain number of cases it has been found advantageous to divide the pronator radii teres. This muscle is often much contracted and, unless released, it helps to prevent free supination and tends to cause the recurrence of its limitation. This muscle may easily be found and divided by another incision on the upper forearm, subsequent to the shoulder operation.

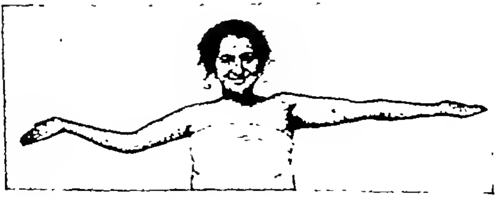


FIGS. 33, 34—Splint used after operation. FIG. 33, front. FIG. 34, back.

Experience has shown that the operation on the plexus in the usual upper arm type of case is unnecessary. In the lower arm type of case, the situation is quite different. Also, it cannot be too strongly emphasized that no operation on the plexus will be of any great use in restoring functional activity to the arm, unless contracted and restricting muscles are divided, and careful after-treatment persisted in for a long period.

In the lower arm type of case, operative treatment on the plexus has been done a number of times without any benefit. The plexus in all cases was found to be so badly torn, and so bound down and invaded by scar tissue, that no kind of repair was possible. This may





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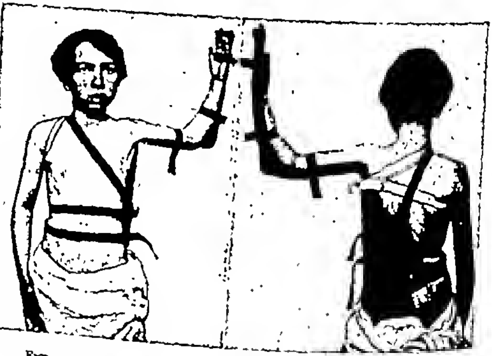

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CHAPTER ELEVEN

PHYSICAL THERAPY IN THE PREVENTION AND CORRECTION OF CERTAIN DEFORMITIES AND DISABILITIES OF THE EXTREMITIES

PHILIP LEWIN, M.D., F.A.C.S.

INTRODUCTION

This chapter was written from the viewpoint of an orthopedic surgeon. The specialty of orthopedic surgery cannot be easily defined. I have diagrammatized the definition as follows:

Orthopedic Surgery is the Science of the	Prevention and Correction	of Deformity
	and the	
	Preservation and Restoration	of Motor Function

As an example of a disease which involves every factor in this definition, I would cite infantile paralysis. If deformity is not prevented it must be corrected; if motor function is not preserved it will have to be restored. Physical therapy is one of the most valuable agents in the preservation and restoration of motor and locomotor functions.

The scope of this chapter includes conditions caused by congenital, traumatic, infectious, neurologic, circulatory, metabolic, endocrine, neoplastic and miscellaneous factors, in so far as they have not been discussed in other chapters.

Speaking in general terms, the orthopedic surgeon is partial to the following physical therapy measures: rest, traction, temporary immobilization, support, radiant heat, gentle massage, active motion, underwater gymnastics, sinusoidal current and diathermy.

The reader is concerned with knowing and understanding, and the orthopedic surgeon with discussing, the indications for the use of physical therapy agents, in what conditions physical therapy is indicated, when to start, when to stop, what to prescribe and when not to

have been due to two things: first, to the fact that it was impossible to repair the plexus; and second, to the fact that, granted that the plexus repair was in part possible, the muscular contractures and joint deformities were not recognized and properly treated, without which the plexus repair would be a waste of time and effort.

Value of Operation.—The prognosis in all upper arm types of cases is good, provided the case is watched from the start and the treatment is properly carried out. Practically all patients with upper arm paralysis are able to raise the arm to the shoulder level and can use the hand and lower arm well, except for varying degrees of supination (Figs. 35, 36, 37). Abduction and outward rotation are rarely regained without division of the contracted muscles, provided they have been allowed to contract.

In the lower arm type, the outlook is not so good, although many of the cases regain use of the upper arm in spite of the persistent paralysis of the lower arm and hand. These cases should all be explored for repair of the plexus as far as possible, but even then very little hope can or should be held out to the parents. The general principles of treatment should, however, be carried out over a long period of time. Much can be done along orthopedic lines for these cases. They should not be generally neglected as they have been in the past, with the statement that nothing can be done, or that they will get well without treatment.

A technician may be compared to an efficient midwife; she may be very clever and capable but does not know the why or wherefore. She must understand the underlying pathology of the conditions she treats.

It is difficult to prove the value of physical therapy. The explanation of the production of results is bound up in several factors, some of which are as follows:

1. The effect upon the circulation, locally and generally.
2. The local absorption of tissue products.
3. Relief from pain.
4. Relaxation of muscle spasm.
5. Release of adhesions.
6. Increase in movements.
7. Raising the threshold of the patient's resistance.
8. The psychologic effect during the various stages of disease, injury or disability.

It is within the limits of definition that the agents or agencies discussed in this chapter are physical therapeutic in nature, or accomplish their effects by physical therapeutic phenomena.

Trauma

Trauma may be acute or continued. Acute trauma may be mild or severe. Continued trauma may be mild or severe. As an example of mild continued trauma, one should consider the pianist and the ballet dancer. Under severe continued trauma, one may consider the iceman, the plumber, the piano-mover and other individuals who carry or lift heavy objects.

Every movement of a joint causes trauma. If the circulation is good, the effects of the trauma are repaired immediately. If repair does not progress as rapidly as destruction, a pathologic condition results. If circulation is impaired, the defect is not repaired, and an area of pathologic change is formed.

The joints most liable to trauma are those of the feet, the fingers, wrist, knee, shoulder, elbow and the hip.

In a discussion of trauma, one may consider trauma as the only factor, trauma as the precipitating factor and trauma which exaggerates a preëxisting condition. As an example of trauma as the only factor, one may consider fracture of the os calcis in a normal individual. As an example of trauma as a precipitating factor, consider the case of an overweight woman of 50 years, who has asymptomatic arthritis in both knees; she falls and injures one knee, lighting up an arthritis. As an example of trauma exaggerating a preëxisting condition, one may consider a knee joint that has a low-grade arthritic condition which is affected by changes of weather but is perfectly serviceable until the woman falls on the sidewalk, bumping her knee, which results in pain, swelling and disability.

employ physical therapy. It is very important to know what procedure to follow in the case of partially or completely stiff joints. One must determine whether rest or movement is indicated. He must determine what type of rest, how long it is to be continued, whether it is to be intermittent or continuous, or whether it should be accomplished by posture in bed, sandbags, slings, traction, splints, braces or plaster-of-paris casts. If movement is indicated, what type of movement, at what intervals it is to be carried out, when it is to be started, and what are the danger signals. When in doubt, one may try movements very cautiously and at infrequent intervals. The reader is referred to other chapters on this subject and to the writings of Sir Robert Jones.

Physical therapy is more closely associated with orthopedic surgery than with any other branch of medicine because the orthopedic surgeon employs physical therapy in almost all his work. He is, therefore, keenly interested in the progress and development of physical therapy.

No orthopedic surgeon today can secure perfect results without the use of physical therapeutic agents. If this statement is true concerning the orthopedic specialist, one can readily understand how much more important it is to the general practitioner who is so often confronted with these same conditions.

Physical therapy aims primarily at treating the pathology, not the etiology, of diseases, deformities and disabilities.

Various orthopedic conditions in which the treatment of physical therapy may be of benefit are lumbago, sciatica, brachial neuritis, bursitis, scoliosis, poliomyelitis, spastic paralysis, brachial palsy, industrial conditions of the bones, joints and nerves, and disturbances of the back, knee, shoulder and other regions.

The treatment should be under the supervision of the orthopedic surgeon. The coöperation of the patient is of paramount importance because so often the treatment is long and tedious.

The administration of physical therapy should be in the hands of a trained individual. By that is meant one who not only thoroughly understands the technic of all branches but has had in addition medical training, in order to direct the treatment intelligently and to appreciate the dangers that may result from ignorance or from errors of omission and commission.

Physical therapy is an important therapeutic agent but it has its limitations, and unless it is used with discretion much harm may be done, and a valuable adjunct in the treatment of many surgical and medical conditions, especially orthopedic, may be lost to use, through its falling into bad repute either as a result of exaggeration and unwarranted claims or of ill-advised or improper administration.

Every physician should understand the principles of physical therapy and should understand the technic sufficiently well to be able to supervise the administration even when given by a competent assistant. In orthopedic surgery, physical therapy is used as a curative agent as well as to restore or improve function.

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1. The effect upon the circulation, locally and generally.
2. The local absorption of tissue products.
3. Relief from pain.
4. Relaxation of muscle spasm.
5. Release of adhesions.
6. Increase in movements.
7. Raising the threshold of the patient's resistance.
8. The psychologic effect during the various stages of disease, injury or disability.

It is within the limits of definition that the agents or agencies discussed in this chapter are physical therapeutic in nature, or accomplish their effects by physical therapeutic phenomena.

Trauma

Trauma may be acute or continued. Acute trauma may be mild or severe. Continued trauma may be mild or severe. As an example of mild continued trauma, one should consider the pianist and the ballet dancer. Under severe continued trauma, one may consider the iceman, the plumber, the piano-mover and other individuals who carry or lift heavy objects.

Every movement of a joint causes trauma. If the circulation is good, the effects of the trauma are repaired immediately. If repair does not progress as rapidly as destruction, a pathologic condition results. If circulation is impaired, the defect is not repaired, and an area of pathologic change is formed.

The joints most liable to trauma are those of the feet, the fingers, wrist, knee, shoulder, elbow and the hip.

In a discussion of trauma, one may consider trauma as the only factor, trauma as the precipitating factor and trauma which exaggerates a preëxisting condition. As an example of trauma as the only factor, one may consider fracture of the os calcis in a normal individual. As an example of trauma as a precipitating factor, consider the case of an overweight woman of 50 years, who has asymptomatic arthritis in both knees; she falls and injures one knee, lighting up an arthritis. As an example of trauma exaggerating a preëxisting condition, one may consider a knee joint that has a low-grade arthritic condition which is affected by changes of weather but is perfectly serviceable until the woman falls on the sidewalk, bumping her knee, which results in pain, swelling and disability.

employ physical therapy. It is very important to know what procedure to follow in the case of partially or completely stiff joints. One must determine whether rest or movement is indicated. He must determine what type of rest, how long it is to be continued, whether it is to be intermittent or continuous, or whether it should be accomplished by posture in bed, sandbags, slings, traction, splints, braces or plaster-of-paris casts. If movement is indicated, what type of movement, at what intervals it is to be carried out, when it is to be started, and what are the danger signals. When in doubt, one may try movements very cautiously and at infrequent intervals. The reader is referred to other chapters on this subject and to the writings of Sir Robert Jones.

Physical therapy is more closely associated with orthopedic surgery than with any other branch of medicine because the orthopedic surgeon employs physical therapy in almost all his work. He is, therefore, keenly interested in the progress and development of physical therapy.

No orthopedic surgeon today can secure perfect results without the use of physical therapeutic agents. If this statement is true concerning the orthopedic specialist, one can readily understand how much more important it is to the general practitioner who is so often confronted with these same conditions.

Physical therapy aims primarily at treating the pathology, not the etiology, of diseases, deformities and disabilities.

Various orthopedic conditions in which the treatment of physical therapy may be of benefit are lumbago, sciatica, brachial neuritis, bursitis, scoliosis, poliomyelitis, spastic paralysis, brachial palsy, industrial conditions of the bones, joints and nerves, and disturbances of the back, knee, shoulder and other regions.

The treatment should be under the supervision of the orthopedic surgeon. The coöperation of the patient is of paramount importance because so often the treatment is long and tedious.

The administration of physical therapy should be in the hands of a trained individual. By that is meant one who not only thoroughly understands the technic of all branches but has had in addition medical training, in order to direct the treatment intelligently and to appreciate the dangers that may result from ignorance or from errors of omission and commission.

Physical therapy is an important therapeutic agent but it has its limitations, and unless it is used with discretion much harm may be done, and a valuable adjunct in the treatment of many surgical and medical conditions, especially orthopedic, may be lost to use, through its falling into bad repute either as a result of exaggeration and unwarranted claims or of ill-advised or improper administration.

Every physician should understand the principles of physical therapy and should understand the technic sufficiently well to be able to supervise the administration even when given by a competent assistant. In orthopedic surgery, physical therapy is used as a curative agent as well as to restore or improve function.

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Forms of Therapy

All forms of therapy, or treatment, can be divided into four types, viz:

1. Medical
2. Surgical
3. Mental
4. Physical

All forms of therapy not included in the first three must, therefore, fall into Class 4.

Class 4, or physical therapy, includes the following:

1. Rest
2. Heat—thermotherapy
3. Fever therapy
4. Massage
5. Hydrotherapy
6. Electrotherapy
7. Heliotherapy—phototherapy—actinotherapy
8. Mechanotherapy including the respirator
9. Medical gymnastics—exercises, swimming, underwater gymnastics
10. Occupational therapy—curative workshop
11. Support
12. Immobilization
13. Manipulative therapy
14. Aids in locomotion

Electrical apparatus is overrated and used frequently as a saver of time and manual labor. No one method is a cure-all or advisable in every case.

There are indeed very few practitioners of medicine and surgery, who have sufficient information to advise the physical therapist exactly what to do for their patients. They should, however, state the diagnosis, the pathology and the reason for sending the patient to the physical therapist, telling him what is desired in the way of treatment of the pathologic condition and whether it is an atrophy, an hypertrophy, an exudate or whatever it may be.

In prescribing physical therapy, one should consider the situation analogous to sending a prescription to the druggist.

Daily treatment may be too frequent.

Many patients do not do well under ambulatory physical therapy, who would, if they were recumbent.

Advice to the physical therapist:

> Do not try to cure the patient in one or a few treatments; it cannot often be done.

Do not discuss other cases or other doctors with patients or doctors.
Do not talk too much.
Do insist upon knowing the pathology.
Do carry out the doctor's orders like a druggist would fill a prescription.
Beware of deep massage over hairy areas in cases of myositis of the neck and lower back.

The physical therapist too often uses his or her own hands instead of encouraging the patient to use his or her own muscles and move his or her own joints.

The importance of the early application of physical methods of treatment is becoming increasingly appreciated. It is important that physical therapy should be applied only by those qualified to do so by special training and experience. A knowledge of anatomy and physiology is fundamental. Much harm can be done and unfavorable criticism broadcast by misapplied physical therapy.

Rest.—Rest includes rest in bed. Rest to the body and limb is accomplished by the use of casts, splints, braces, frames and sandbags.

Bed—Recumbency.—Most mattresses sag in the middle, from the sides and both ends. For that reason, they should be made rigid by inserting boards or a wooden frame between the mattress and the spring. In some cases, a double mattress is desirable with the boards or wooden frame under the lower mattress. This is of considerable value in back and leg cases, especially for those patients who are in plaster of paris.

Heat.—*Thermotherapy* is the application of heat or cold or both, alternately, as a means of treatment. The chief agents are dry heat, moist heat, cold, and alternate heat and cold. The methods of administering these agents are as follows:

Dry heat	Hot water bag Hot sand Hot brick Electric pad Electric lights—cabinet—baker Hot metal flask Hot chemical bag Hot air blower
Moist heat	Hot baths Hot applications with or without drugs Steam baths

Cold { Ice bag
Cold applications
Cold air blower

Contrast heat and cold { *Bath*
Spray
Applications

Heat may be produced by ointments, liniments and plasters.

Plasters, adhesive and bandages serve to retain the patient's own heat.

Pilocarpine, 1/10 of a grain hypodermically, is frequently used in connection with heat in order to induce early perspiration.

The chief indications for thermotherapy are sprain, strain, fibrositis, myositis, arthritis and after various traumas.

In discussing radiant heat, Putti contrasts the effect of diathermy and the spirit lamp. He believes that the so-called Bier box, which consists of a wooden case containing a current of hot air produced by a spirit lamp, is superior to diathermy. He believes that the heat which produces this type of active hyperemia is the most effective form of physical therapy in the treatment of infectious or traumatic non-articular arthritis. Under the action of intense heat the pain diminishes, contractures relax, and the joint becomes more mobile.

Putti emphasizes the importance of active hyperemia. The mechanism by which hyperemia acts is a complex one and not completely understood. Vasodilatation, by activating the interchange of body fluids, increases the power of defense, contributes to the neutralization of toxins, stimulates the processes of repair and, by an inhibitory action on the nerve endings, reduces the pain.

The steam or Russian room is one which is provided with live steam which is introduced beneath a table through perforated metal pipes. Its chief advantage is the production of increased cutaneous elimination. The same holds true for the electric light cabinet.

Paraffin Wax Bath.—I have seen the paraffin wax bath used to great advantage in the Royal Northern Hospital in Liverpool by Mr. Armour. It was used especially in industrial hand and foot cases. The temperature of the paraffin was about 104° F. (40° C.). The member was kept in it for about 20 minutes.

Anodyne Lotion and Fomentations.—In the treatment of non-tuberculous, painful, stiff joints, the application of an anodyne lotion, used in conjunction with fomentations, may be very effective in relieving pain and increasing movement.

My favorite lotion has the following formula:

℞ Tinct. opii 30
Liq. plumbi subacet. dil. 40
Phenolis ½% 50
Ext. hamamelidis 60

M. et ft. lotio.
Sig.: Externally as directed.

It is used in the following manner:

Compartment A
1. Apply four layers of gauze over a wide area.
2. Saturate the gauze with the lotion after the bottle has been well shaken.
3. Apply oiled muslin, oiled silk or rubber sheeting.

Compartment B
4. Apply flannel or wool wrung out of hot water.
5. Apply oiled muslin, silk or rubber sheeting.

Compartment C
6. Add hot water bottle.
7. Cover everything with Turkish towels.

If possible, elevate the affected part. Change hot water bottle every two or three hours if necessary. Add lotion to gauze three times a day.

Fever Therapy.—Fever therapy includes the reaction obtained by the intravenous injection of foreign protein such as typhoid vaccine, aolan and milk; and subcutaneously, by Coley's toxin.

The subject of fever therapy is discussed by Neymann in Volume I. From the orthopedic point of view, it is indicated in certain cases of arthritis and circulatory disturbances.

Massage.—Massage may be of various types as regards movements and force applied. Olive oil, cocoa butter or talcum may be used to prevent irritation of the skin. Massage is useful in assisting nutrition and mobility.

Massage is indicated especially in sprains, strains, dislocations, fractures, stiff joints, following amputation, following infantile paralysis, peripheral nerve injuries and occasionally in spastic paralysis.

It is of real value in the preoperative and postoperative treatment of infantile paralytic conditions. Mennell says that in the treatment of recent injuries, one cannot heal torn fibers by massage, but he can assist in restoring the circulation upon which the repair depends.

It is claimed for massage that it promotes metabolism, maintains nutrition, restores strength to weak muscles, prevents formation of adhesions and helps break them up if already formed, breaks up fibrosis, hastens repair after injury, prevents and helps restore lost function in muscles and joints, and renders voluntary motion in diseased or injured parts easier.

Reference to various chapters in this series shows one the wide scope of usefulness of massage. Massage should be used as soon as possible and should be very gentle at first, gradually increasing in strength or severity.

The contraindications for massage are hyperesthesia in poliomyelitis, pain and infection. In cases of fracture or dislocation there is danger of displacing the bone fragments.

Hydrotherapy.—Hydrotherapy is the application of water at various temperatures and pressures and with various constituents.

Its value lies in the effect upon the circulation of the skin and the tonic action upon the nerves locally and generally. The chief pieces of apparatus are the shower, needle-spray, hose-spray, and the sitz and whirlpool baths. The last is a bath for the extremities in which the water is kept in motion.

The application of hydrotherapy to the upper and lower extremities is valuable, especially in sprains, strains and infections.

The Short Cold Bath.—Riley presents a complete and instructive study of the effects of the short cold bath, meaning a bath at from 90 to 55° F., for one-half to three minutes (usually one minute).

Electrotherapy.—Electrotherapy is the application of electricity as a therapeutic measure. The chief types of currents as described by Kovacs are: (1) the galvanic, (2) the interrupted galvanic, (3) the slow (galvanic) sinusoidal, (4) the surging or interrupted sinusoidal (modulated alternating), (5) the faradic (asymmetric) interrupted alternating, (6) the high frequency (diathermy) and (7) the static. There is a great advantage in bed treatment as compared with ambulatory treatment. It is of greater value to bring the apparatus to the patient than to put the patient on a stretcher or in a wheel chair and transport him or her to the apparatus. Diathermy and the galvanic current are the most valuable forms from an orthopedic standpoint. Electric cabinets, bakers and lights owe their chief virtue to the production of heat.

The indications for diathermy consist in those conditions where deep heat is valuable, such as in sprains and strains, synovitis, arthritis, myositis and fibrositis. Diathermy should be very carefully used in the presence of near or distant suppuration.

The Smart-Bristow coil is an apparatus for producing graduated muscular contraction and is indicated in sprains and strains, myositis, fibrositis, arthritis and atrophy of muscles. The present Smart coil, which has recently found its way into America, through the efforts of Dr. William O'Neill Sherman, is a much larger apparatus and is probably the best means at the present time of producing graduated muscle contraction; it is indicated in sprains, strains, atrophy of muscles from disuse and disease, from immobilization and various other factors, and in arthritis, especially of the atrophic type.

Among the pathologic disturbances most amenable to diathermy are sprained joints, inflammatory phenomena accompanying fractures, simple arthritis and many forms of inflammation without suppuration in which heat tends to hasten the resolution of the inflammatory products and thus shorten disability. Acute and subacute neuritis, such as sciatic neuritis, and myositis, such as lumbago, often respond extremely well to diathermy. Certain forms of acute and subacute gonorrheal inflammation likewise yield more quickly under diathermy. In these conditions relief from pain is one of the outstanding advantages of the treatment.

In the chronic forms of arthritis the effect of diathermy is not so uniformly striking. In many cases, however, partial or complete relief from pain and reduction of swelling is obtained.

If diathermy treatment is instituted at a reasonably early date, the trophic lesions in many cases of endarteritis or thrombo-angiitis obliterans or diabetes can be stopped, and much damage prevented or mutilating operations made unnecessary.

Heliotherapy.—The subject of heliotherapy in tuberculosis has been covered by Rollier (Vol. III). However, there are many other conditions affecting the extremities in which heliotherapy is a very valuable agent. These include nutritional and circulatory disturbances, arthritis, myositis, fibrositis and synovitis.

Heliotherapy is of great value in toning up atrophic muscles. Its value in nutritional conditions such as rickets is well known.

Heliotherapy is of great value in atrophic arthritis. It is surprising to see the excellent muscular tone of individuals who have been under heliotherapy for years. Unquestionably, if these patients had not had heliotherapy, the enforced recumbency in bed would have resulted in marked atrophy of muscles and bones. I prefer the term *helioaerotherapy.*

Phototherapy means treatment by various lights. The ultraviolet lamp is an imitation of sunlight but a very efficient one. The exact action has not been determined. The two main types are the quartz and the carbon.

Lamps may be air cooled or water cooled. The dosage of phototherapy depends upon the type of light used, the individual characteristics, i.e., blonde or brunette, the distance from the body and the duration of exposure.

The principles of heliotherapy apply to phototherapy. The infrared light owes its virtue to the radiation and penetration of heat.

The quartz ray is better known as the ultraviolet ray. It is called the actinic ray because it has the power to excite chemical action and has more effect upon photosensitive paper than other light rays, and is called ultraviolet because it lies just beyond the violet of the visible spectrum.

The application of the ultraviolet ray is followed by two reactions—a local and a general one. The local is manifested by various degrees of erythema; the general, by various blood chemistry reactions, the sum total of which may be said to be decidedly beneficial in many conditions.

One cannot allow this opportunity to pass without calling attention to the fact that phototherapy has been used indiscriminately for any and every condition. This state of affairs is deprecated and should be condemned. Ultraviolet radiation has considerable value from a physiologic point of view, but this has been greatly overdone and abused.

Phototherapy is indicated in atrophic muscle and joint conditions, in nutritional disturbances, tuberculosis and arthritis, in recovery from fractures, and sprains and strains. In general, the indications and contraindications are similar to those for heliotherapy.

Mechanotherapy.—Mechanotherapy includes various mechanical apparatus which perform passive movements of the limbs, as illustrated by the Zander apparatus.

The Europeans are more partial to this type of treatment than are the Americans. In most of the larger European clinics, one finds immense rooms with innumerable pieces of Zander apparatus. This apparatus is applicable to almost every type of injury and condition. One sees a patient having his thumb moved for him at a regular rate—another patient having his fingers moved at a certain rate and with a certain amount of force—another is having his foot supinated, pronated, dorsiflexed, plantar-flexed or circumducted. One sees a knee being flexed or extended at rhythmical intervals or a hip being abducted, adducted, flexed, extended or circumducted—a shoulder moved through its range of motion—another an elbow—another a wrist, and so on. There is no doubt that there is considerable value in the Zander apparatus, but one should not lose sight of the fact that "all physical therapy must be mixed with brains" in order to accomplish the desired results, and there is no substitute for human hands and human brains. In America, one might say, this form of Zander apparatus treatment has not been very popular. Less cumbersome mechanotherapy has been developed, especially by McKenzie. It is a valuable adjunct to the restoration of movement and function.

Respirator.—The Drinker respirator has been described in Volume I. However, from the standpoint of the orthopedic surgeon in the treatment of infantile paralysis, it may be said that, in certain cases, if the Drinker apparatus is not at hand and functioning, all the orthopedic surgeon's armamentarium may not save the patient's life. The indications are to carry a patient through a transitional stage of respiratory paralysis. It may be used in cases of intercostal paralysis to give those muscles a rest.

Medical Gymnastics—Exercises.—Medical gymnastics or exercises consist in muscle education and reëducation. Their chief value lies in the treatment of patients with infantile paralysis, spastic paralysis, brachial birth palsy, scoliosis, arthritis, postural disturbances and neuromuscular conditions. The equipment of the gymnasium consists of parallel bars, upright bars, wall ladders, stall bars, tables, benches, chairs, wall mirrors, wall exercisers, traveling rings, horses and floor mats.

Active movements are those carried out by the patient. Passive movements are those performed by the physical therapist. The latter are employed chiefly when active movements are impossible because of weakness, pain or lack of coöperation, or in the presence of adhesions that limit movement. Resistive movements are those performed by the patient against the resistance of the physical therapist, and *vice versa*.

Gymnastics include those performed on land and those in water.

SWIMMING—HYDROGYMNASTICS.—Hydrogymnastics is a term coined by Lowman and includes special types of exercises performed in the water with and without support. This valuable method is discussed in Volume III.

Occupational Therapy.—The importance of occupational therapy cannot be overemphasized.

The chief indications for occupational therapy in diseases, deformities and disabilities of the extremities lie in the treatment of such conditions as fractures, dislocations, infantile paralysis, spastic paralysis, sprains and strains, myositis, fibrositis and arthritis.

Because it involves active movements, it may be employed at a very early period during treatment. The subject of curative workshops is treated in Volume I.

By giving the patient purposeful acts to perform, making them very interesting and educational to him and by stimulating his ego, one may accomplish very much. It is very rarely that the patient will overdo to the extent of doing harm, because he is guided by discomfort and pain.

Mock and Abbey state that back injuries form a large percentage of the group in which physical therapy and occupational therapy combined can be of inestimable value to the surgeon. In cases of nerve and tendon sutures, muscle transplantation, infantile paralysis, chronic arthritis, osteomyelitis, tuberculous and nontuberculous joint disease, occupational therapy has its important place. In some cases the application is purely diversional while the affected parts are at rest. In others, the work consists in reëducating the joints, muscles and nerves to their normal functions. For those who will not again be able to carry on their work, a new set of muscles or nerves must be trained to function. Neither physical therapy nor occupational therapy should be carried to the point of fatigue; occupations should be given which

are best fitted to meet each peculiar condition of the case. The patient should be encouraged and stimulated, and his achievements recognized and rewarded.

Support.—In the application of bandages, one must be very careful not to interfere with circulation. In adhesive strappings, the important thing is to avoid constriction of circulation. One should try to avoid in every case the complete encircling of a limb by one strip of plaster. In the application of splints or braces, one may say that they may be used or abused, depending upon the skill and experience of the person who applies them. Splints and braces are not universal but must be individualized to the particular patient.

Immobilization.—Immobilization includes bandaging, strapping, splints, braces and casts.

BANDAGES.—Bandages are made of gauze, muslin and variously woven materials which are resilient and, therefore, can act as support and compression. It is important in the application of the bandage that no constriction of the circulation results. If the limb swells or becomes cyanotic, the bandage is evidently too tight. There are various types of resilient bandages, such as the Ace and the Tetra bandages. These bandages are woven so that the bandage acts as a resilient support. They have a definite place in the treatment of varicose veins and other circulatory disturbances. There are combination bandages with adhesive on one or both sides.

SPLINTS.—Various types of splints are illustrated in Figures 16, 54, 55, 56 and 57.

BRACES.—Various types of braces are illustrated in Figures 7, 11, 13, 14, 16, 54, 55, 56, 57, 62 and 64.

The surest way to get rid of braces is to put them on early and wear them faithfully until they are no longer necessary.

CASTS.—Every one who engages in physical therapy should know the principles of plaster-of-paris technic and how to handle casts, especially those that are bivalved.

Various types of plaster casts are illustrated in Figures 3, 5, 8, 10, 11, 15, 51, 52, 53 and 64.

A cast never made a joint permanently stiff. Any stiffness caused by a cast quickly disappears. It is the disease or trauma that causes stiffness. When the disease or trauma predisposes to joint stiffness, and early physical therapy is necessary to prevent stiffness, the cast, if prolonged, interferes with physical therapy and therefore, to that extent, is responsible.

Plaster bandages are usually made of crinoline or tarlatan into the meshes of which is rubbed the plaster-of-paris powder. The band-

age is then rolled and stored until used. The most common type of crinoline is that whose meshes are 28 or 32 to the inch.

When ready for use, the plaster bandage is soaked in a bucket two-thirds full of lukewarm water. The addition of salt hastens, and sugar retards, the setting. The bandage is laid on its side until all the air bubbles have ceased to appear at the top of the water, which means that all the plaster has been saturated. It is then lifed out, both ends squeezed and twisted through a small arc, to get rid of the excess; it is untwisted, flattened out and the end of the bandage found and unraveled a few inches, when the bandage is ready to be applied. Plaster-of-paris bandages should be applied over one or two layers of stockinet. One layer of stockinet is most commonly used, then a layer of sheet wadding, then a gauze bandage and, finally, the plaster bandage. If two layers of stockinet are used, no other padding is used except over bony prominences such as the patella, the ankle bones and the heel. One should be careful to pad the Achilles-tendon region because of danger of causing pressure.

One hears the expressions "corrective" cast, splint or brace. They are misnomers. They are instruments of retention, that is, apparatus to maintain correction or overcorrection after those positions have been obtained by some other means, such as manipulation or operation.

ADHESIVE.—Adhesive strappings are of value in sprains and strains. Adhesive strapping of a foot and ankle is found in Figures 40, 41, 42 and 43; lower back, Figures 60 and 61; pelvis, Figures 60 and 61. Other regions frequently strapped with adhesive are the metatarsal, big toe, little toe, knee, hip and chest.

Elastic supports for the metatarsal region, the ankle, the leg, lower leg and the entire leg are of some value, especially in those cases of circulatory disturbance in which there is swelling of the limb, such as varicose veins, and in traumatic conditions, such as sprain and strain.

FRAMES.—The most common frames in use are those of Whitman and Bradford. The Bradford type is a gas-pipe frame made usually of ⅜- to ½-inch gas pipe. This is rectangular in shape with an elbow at each of the four corners. Over this frame there is stretched a canvas. The canvas may be in one, two or three pieces.

The Whitman type is a curved Bradford frame.

A Balkan frame is an overhead structure consisting of four uprights corresponding with the posts of the bed—two longitudinal boards or bars and two cross bars. It is used primarily for overhead suspension in cases of fractures. A trapeze is suspended so that the patient may pull himself up.

Aids in Locomotion.—These include crutches, canes and artificial limbs.

CRUTCHES.—Crutches are illustrated in Figure 1.

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The patient usually learns the best manner of using one or two canes.

When one cane is used it should be placed on the weak or disabled side.

When two canes are used they should be used in a manner similar to that employed with crutches; viz., protrusion of the right cane, then the left foot, next, the left cane and, finally, the right foot.

ARTIFICIAL LIMBS.—The subject of artificial arms and legs is discussed in detail in Volume II.

Manipulative Therapy; Brisement Forcé.—Manipulative therapy includes that performed gently and over long periods, and that performed quickly under anesthesia. Local, spinal or general anesthesia may be used.

One should be careful in performing manipulation under anesthesia except in a few conditions.

Brisement forcé may be used in a refracture of bones to correct deformity. This was a common procedure during the late war.

Manipulative therapy is indicated principally in those conditions which follow several weeks after an injury; that is, those conditions due to adhesions rather than to arthritis. Manipulation is indicated in those conditions where, because of a comfortable posture during an acute illness, a person develops a contracture, such as an adduction contracture of the thigh or of the shoulder, or a flexion contraction of the elbow or knee.

The following are brief outlines of the technic in manipulating representative joints:

1. *Hip:* With the patient completely anesthetized and the pelvis and opposite leg secured firmly to the table, the affected hip is flexed with the knee flexed; it is then extended, then flexed with the knee extended. It is then adducted, abducted, extended with the knee extended, circumducted, then rotated inward and outward. It is then hyperextended over the edge of the table. In some cases the adductor tendons must be divided before abduction can be performed.

2. *Knee:* With the pelvis and the other limb held firmly, the knee is gently flexed, then extended two, three or four times; it is not used as a pump-handle. In all cases of manipulation of the knee one should see that the foot and the hip on the same side can be put through the normal range of movements.

3. *Ankle:* Manipulation of an ankle includes dorsiflexion, plantar flexion, inversion, eversion, supination, pronation, circumduction; dorsiflexion and supination at the same time are the *sine qua non* in manipulation of the ankle.

4. *Foot:* Manipulation of the foot includes that of the subastragalar joint, through the tarsal joints, through the tarsometatarsal joints

Crutches are measured for adults by subtracting 16 inches from the height of the individual. Another method is to measure the distance from the axilla to a point 8 inches outward from the outer border of the foot. Crutches come in even sizes only and, if odd sizes are used, the larger size should be prescribed and then cut off. Rubber tips

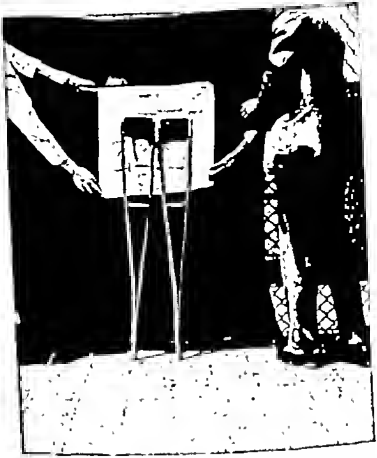

FIG. 1.—Special type of crutch. Substitution of a brachial cuff for the axillary rest.

should be applied, and axillary pads should be added to that portion to prevent irritation and crutch palsy.

If a patient is allowed to bear weight on both legs, the proper method of progression is as follows: place one crutch forward, then the opposite foot; then the second crutch and then the remaining foot. If a patient walks with crutches and one leg, he should put both crutches forward, then the leg, the affected leg either held flexed or, preferably, with a block under the shoe (heel and sole) of the well side in order to keep the injured part off the ground, without tilting the pelvis and spine.

CANES.—Canes are used during the stage after crutches are no longer necessary. They may be used in minor conditions where crutches are not required.

The patient usually learns the best manner of using one or two canes.

When one cane is used it should be placed on the weak or disabled side.

When two canes are used they should be used in a manner similar to that employed with crutches; viz., protrusion of the right cane, then the left foot, next, the left cane and, finally, the right foot.

ARTIFICIAL LIMBS.—The subject of artificial arms and legs is discussed in detail in Volume II. .

Manipulative Therapy; Brisement Forcé.—Manipulative therapy includes that performed gently and over long periods, and that performed quickly under anesthesia. Local, spinal or general anesthesia may be used.

One should be careful in performing manipulation under anesthesia except in a few conditions.

Brisement forcé may be used in a refracture of bones to correct deformity. This was a common procedure during the late war.

Manipulative therapy is indicated principally in those conditions which follow several weeks after an injury; that is, those conditions due to adhesions rather than to arthritis. Manipulation is indicated in those conditions where, because of a comfortable posture during an acute illness, a person develops a contracture, such as an adduction contracture of the thigh or of the shoulder, or a flexion contraction of the elbow or knee.

The following are brief outlines of the technic in manipulating representative joints:

1. *Hip:* With the patient completely anesthetized and the pelvis and opposite leg secured firmly to the table, the affected hip is flexed with the knee flexed; it is then extended, then flexed with the knee extended. It is then adducted, abducted, extended with the knee extended, circumducted, then rotated inward and outward. It is then hyperextended over the edge of the table. In some cases the adductor tendons must be divided before abduction can be performed.

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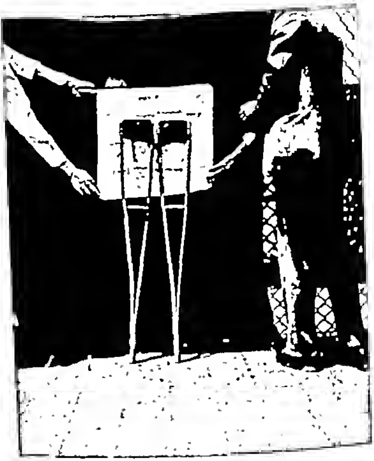

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FIG. 2.—Extreme type of congenital clubfoot, talipes equinovarus in a boy of 12 years, who had had no treatment. Note the large bursae in the regions of the cuboid bones. (Courtesy of Dr. John L. Porter.)

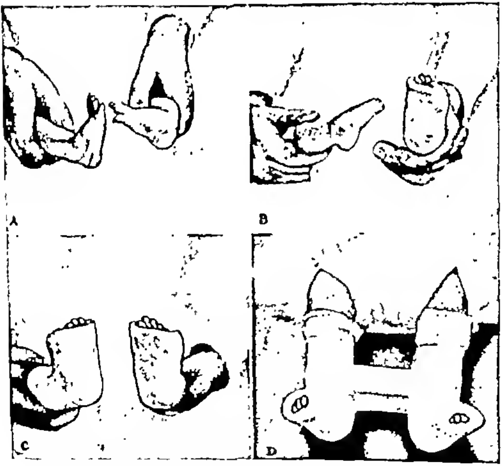

FIG. 3.—Lewin type of cross-bar cast for congenital club feet. A, congenital club feet in a child 11 days old; B, one foot corrected and in plaster cast; C, both feet corrected; D, cross bar made of tongue depressors to maintain outward rotation of the legs.

and through the metatarsophalangeal joints. In the metatarsal joints the important consideration is plantar flexion.

5. *Shoulder:* With the patient entirely flat and secured to the table, the shoulder is first manipulated gently in forward flexion with the elbow flexed; then forward flexion with the elbow extended, forward flexion with the forearm both in supination and pronation, gentle abduction, forced abduction (holding the scapula firmly), backward extension of the arms, circumduction of the shoulder and complete internal and external rotation. The most important movements that must be obtained are abduction and external rotation.

6. *Elbow:* The elbow is flexed and extended three or four times with the forearm both in pronation and supination.

7. *Wrist:* The wrist should be dorsiflexed, palmar-flexed, forced laterally, radialward and ulnarward; the important considerations are dorsiflexion and supination.

8. *Hand:* The hand must be manipulated so that it can be put in the position of grasp—as though it were grasping a tumbler.

9. *Neck:* In manipulating the neck one should be very cautious. Produce gentle flexion of the head, extension of the head, lateral bending so that one ear almost touches the shoulder of the same side, then the other side, then gradual rotation to the right and rotation to the left. The reader is warned that manipulation of the neck is one of the most delicate, and it may be one of the most harmful, procedures to which an individual may be subjected.

The conditions which may cause disabilities and deformities of the extremities constitute a very long list, most of which have been mentioned in other chapters. Those not discussed in detail will be included in this chapter. Special conditions include congenital, infectious, traumatic, mechanical, static, postural, neuropathic and functional disorders.

Congenital Defects and Deformities

Under congenital defects and deformities, the most important to be considered are clubfoot and congenital dislocation of the hip.

CLUBFOOT

Clubfoot may be congenital or acquired.

In clubfoot, the two main types are congenital equinovarus and calcaneovalgus.

$$\text{Talipes} \quad \left\{ \begin{array}{l} \text{equinus} \\ \text{calcaneus} \end{array} \right.$$

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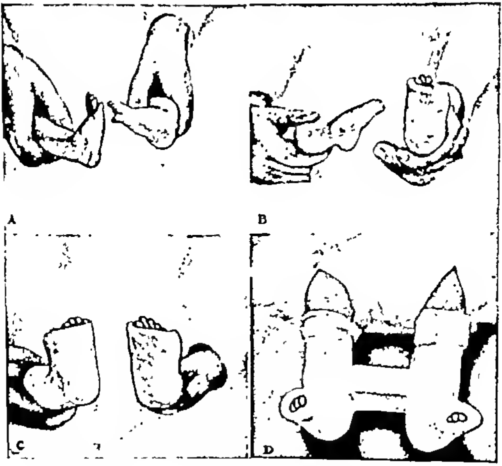

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taneous reduction. In the older cases, treatment includes manipulation under anesthesia, retention in plaster casts which are changed in periods ranging from 3 to 6 months, then follow-up treatment which includes exercises and baths, such as the brine bath of Denucé, and the Galeazzi, Putti and Ridlon manipulations. Open operations are required in those cases which cannot be reduced by the closed method or in those hips which will not stay reduced by the closed method.

The chief manipulations or maneuvers for the reduction of congenital dislocation of the hip include those of Paci, Lorenz, Galeazzi, Putti, Ridlon, Bradford, Davis and Calot. Every textbook of orthopedic surgery describes some of these methods. At the time of change of the cast and following its final removal, bathing of the hips and lower extremities in warm water, and application of heat followed by gentle massage are indicated. As a rule these patients can be trusted to return the legs to normal position by being allowed to exercise them cautiously, especially in warm water.

CONGENITAL DISLOCATION OF THE KNEE

Congenital dislocation of the knee is a rare deformity characterized by genu recurvatum or a backward curving of the knee joint. The early treatment consists in gentle manipulation to flex the knee and the application of a splint or plaster cast to hold it in the flexed position.

MacFarland and McMurray have devised an operation, sectioning part of the quadriceps femoris muscle, followed by flexion of the knee. If the child is seen and treated very early, operation is rarely necessary.

CONGENITAL DISLOCATION OF THE SHOULDER

Congenital dislocation of the shoulder is a very rare deformity. There are not more than 25 instances reported in the literature, several of which are not authentic. The treatment consists in gentle manipulation and retention followed by physical therapy, including gentle massage and more gentle movements.

CONGENITAL FLATFOOT

The etiologic factor of importance in congenital flatfoot is heredity. It is more often transmitted from the father's than the mother's side. The importance of the accessory scaphoid should not be overlooked. This is an adventitious bone in the region of the tarsal scaphoid. The important factors are the early recognition and early treatment. The best early treatment is a plaster-of-paris cast maintaining the posterior portion of the foot in supination, with the fore part of the foot in pronation; that is, the posterior half of the foot should be tipped outward

The treatment may be divided into early, intermediate, and late. Treatment includes manipulation, overcorrection and retention in casts, braces or splints. In the final stages of treatment, one prescribes proper shoes with modifications, exercises, massage and manipulation.

When one finds congenital equinovarus, he produces a calcaneovalgus and *vice versa.*

Pes planus is flatfoot. Metatarsus varus is "pigeon toes." About 75 per cent of congenital clubfeet are of the type in which the toes are pointed downward and inward. This type occurs once in about 1000 births; 65 per cent are in males, and 57 per cent are one-sided.

The deformity is usually said to be due to position *in utero*; heredity is found to be a factor in 5 per cent of the cases. About 30 per cent of the cases are in the first-born.

The chances of cure depend upon the age, the type and degree of deformity, the degree of rigidity, the proper treatment and the persistence of the treatment and observation. Active treatment may be necessary for months, and care and supervision for years. The long narrow foot is much more amenable to treatment than the short chubby foot.

Treatment.—The treatment for clubfoot may be applied at birth, during infancy, during childhood or in adult life; but the earlier the better. The object is to correct the deformity as soon as possible and to maintain the correction until proper use of the foot has made it permanent. Some form of treatment should be instituted immediately. The means of correcting the deformity are manipulation (with or without anesthesia), the use of casts and braces, and operation. Operation is rarely necessary when the patient is seen soon after birth. The various methods of retention consist of bandages, adhesive strapping, plaster-of-paris casts and braces.

I cannot recommend too strongly the use of plaster of paris (even though the infant be but one hour old) to retain a foot in the corrected position which has been obtained by gentle manipulation. Massage, exercises and modification of shoes are other measures of importance. In older individuals, operations on the bones, tendons and other tissues may be necessary.

In clubhand the treatment includes manipulation, retention, massage, further manipulation, braces and exercises. Operation may be necessary.

CONGENITAL DISLOCATION OF THE HIP

Congenital dislocation of the hip is the most important congenital dislocation. The displacement may be upward, backward or forward. The most common is upward and backward. Early treatment includes what Putti has described as a triangular frame which is attached to the child's legs so as to produce abduction, which usually results in spon-

FIG. 6.—New-born baby with brachial birth palsy of the left arm treated by means of a padded wristlet and a strap attached to the head of the basket to maintain abduction of the upper arm.

FIG. 7.—Brachial birth palsy in a child of 18 months; brace maintaining abduction and external rotation of shoulder, flexion of elbow, supination of forearm, dorsiflexion of wrist and extension of fingers.

FIG. 4.—Spastic paraplegia (Little's disease) illustrating adductor spasm producing cross-legged progression.

FIG. 5.—Plaster-of-paris casts of both legs with a cross bar maintaining abduction, in a child who had adductor spasm due to spastic paralysis. She was treated by obturator neurectomy. In some of these cases, tenotomy of the adductors is also required.

sprain, strain, rupture of muscles, rupture of tendons, flat feet, knock knees and bowlegs. These conditions are described at length in other chapters.

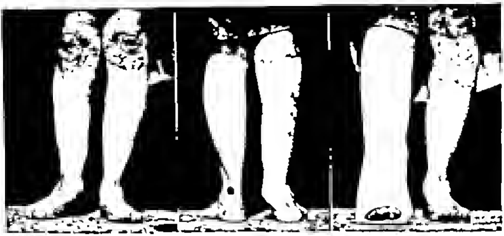

FIG. 8.—Traumatic right flatfoot; (a) front view; (b) rear view; (c) corrected in a plaster cast.

In regard to trauma and postural cases, practically all physical therapy agents have been discussed in the chapters on fractures and dislocations in joint injuries (Vols. II and III).

SPRAINS AND STRAINS

It has been stated that "a sprain is worse than a break." This is grossly untrue because most sprains are mistreated. The proper treatment for a sprained ankle, for example, is absolute rest and elevation of the limb, the application of cold and a compression bandage. In athletic individuals, weight-bearing should be encouraged. In others, it is contraindicated.

Mennell advises early movement and massage without fixation.

Smart advises the early use of graduated muscle contractions by means of his electric coil and no immobilization.

RUPTURE OF MUSCLES

In cases of rupture of a muscle the early diagnosis is important. The treatment includes rest, relaxation of the muscle, application of cold and retention support. Recently, it has been advised to inject novocaine into the muscles to cause relaxation. Heat, massage and gentle active movements are indicated.

and the fore part of the foot tipped inward so that the big toe rests on the cast. The cast should be replaced every two or three weeks. It may be followed by adhesive strapping or, preferably, a brace. Modifications of the shoes are very important and consist in building up the inner border of the heel and the outer border of the sole. Felt pads in the shoes are of value in supporting the longitudinal arches. Exercises should be started as soon as the child can comprehend. Massage is important and contrast sprays may be used for older children.

SPASTIC PARALYSIS

The causes of spastic paralysis are intra- and extra-uterine. The intra-uterine causes are defects or conditions within the skull, such as cysts and hemorrhage. The obstetric causes are trauma during, and immediately after, birth. The latter is illustrated by vigorous efforts at resuscitating a "blue baby." The treatment consists in prophylaxis and curative measures, prophylaxis including gentleness in delivery. The curative measures include the following: lumbar puncture, operation, swimming, stretching of contracted structures, walking, using a walker or crutches, braces and neuromuscular training.

In the treatment of spastic paralysis, one should emphasize the value of heat in order to relax muscles, withholding massage, using gentleness in handling the patients, to the extreme degree, and active movements. A movement directed by the brain and carried out by the proper muscle or group of muscles, with no overflow of nerve impulses producing purposeless movements, is the acme of performance.

Lowman has emphasized the value of a 10 per cent increase in temperature of the water used in swimming over that used for poliomyelitis cases.

BRACHIAL BIRTH PALSY

In brachial birth palsy the important points are early recognition and early treatment. A new-born child with the diagnosis of brachial birth palsy should have its arm suspended from the top of the crib by a sling in the form of suspension guy ropes. A very simple wire brace of the Sever type should be made. Physical therapy follow-up includes massage and gentle manipulation. Operations are necessary in certain cases. They usually are required in those cases that have been neglected. The most important operation is the one known by the name of Sever in which the pectoralis major and the teres minor tendons are cut. In some cases the coracobrachialis and subscapularis are also released. Kleinberg has recently advised a capsule plastic operation which is evidently very beneficial.

TRAUMATIC CONDITIONS

Traumatic conditions include industrial, occupational, mechanical or static. These include fracture, dislocation, fracture-dislocation,

RUPTURE OF TENDONS

Rupture of the tendon often requires suture, which should be done early so that active motion can be instituted as soon as possible. Splints, heat, massage and gentle active movements are indicated.

FRACTURES

In the treatment of fractures, one must emphasize the importance of rest, reduction, retention, early active motion, heat and physical therapy. Some advise occupational therapy as being of greater value than physical therapy.

This subject is discussed at length in Volumes II and III.

DISLOCATIONS

(See Lindsay and Brown, Vol. III.)

CONDITIONS OF INFECTIOUS ORIGIN

Infectious conditions include tuberculosis, syphilis, Charcot's joint, syringomyelia, infections with pus organisms, infections with unusual organisms, osteomyelitis, infantile paralysis and encephalitis.

The physical therapeutic measures that are of value in infections are heat, in the form of radiant heat or fomentations, elevation, ultraviolet and roentgen-ray therapy, and hydrotherapy in the form of packs. One must be careful to prevent contractures, deformity and adhesions. The technic of incisions and drainage is not included in this chapter.

TUBERCULOSIS

In the treatment of tuberculosis of bones and joints, the important factors are rest, proper splinting, prevention of deformity, correction of deformity if it has occurred and preservation of function, or the restoration of function if it cannot be preserved.

In the treatment of tuberculosis of bones and joints, many physical therapeutic agents are of great value. These include rest, recumbency, support, immobilization, plaster-of-paris casts, braces, therapeutic baths, heliotherapy, phototherapy and occupational therapy.

Arthrodesing or stiffening operations are of great value. They are performed on the spine, hip, knee, ankle, shoulder, elbow and wrist. The reader is referred to textbooks of orthopedic surgery for descriptions of these operations.

FIG. 9.—Lewin's method of treating fracture of the clavicle in young children, illustrating the method of obtaining backward displacement of the shoulders by means of a metal or wood bar. While the bar is in place, a figure-of-eight double spica is applied. This allows free motion of the arms. For a day or two it is advisable to apply a sling. In this method of treatment a plaster-of-paris double spica may be used.

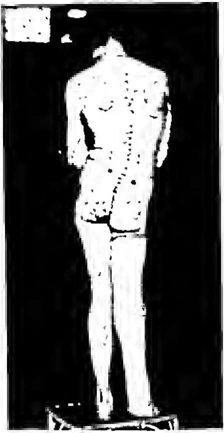

FIG. 11.—A girl of 16 years who had infantile paralysis at the age of 2 years. Note total right scoliosis with the shortening of the right leg, which produced an inequality of the gluteal creases and dimples in the regions of the posterior superior iliac spines.

FIG. 12.—Extreme type of infantile paralysis with high degree of deformities and disability.

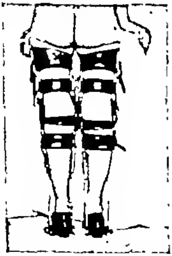

FIG. 13.—Caliper braces with lock joints at the knees used on a patient who had infantile paralysis.

FIG. 14.—Two long-leg braces and a body brace for extensive paralysis due to anterior poliomyelitis.

FIG. 10.—A boy of 10 years with tuberculosis of the spine treated by a Hibbs' spine fusion followed by a body cast.

SYPHILIS—CHARCOT JOINT

In the treatment of syphilis, one must be careful to prevent deformity and, if deformity has occurred, it should be corrected. The various physical therapeutic means included are massage, splinting, braces, pyretotherapy and diathermy. Specific treatment including malaria and arsphenamine is not discussed in this chapter.

OSTEOMYELITIS

In the treatment of osteomyelitis, three methods will be briefly mentioned:

1. The Orr method, which includes good surgery, vaseline pack and plaster-of-paris casts. The principle of this includes rest of the wound by means of the vaseline pack, and rest of the limb by means of the cast. No sutures are inserted, as a rule.

2. The method popularized by Baer, which is the treatment by means of maggots, called the "living scavenger treatment." By a special process the eggs of the maggot are sterilized and the live maggots are inserted into the wound. There are numerous reports of excellent results following this method.

FIG. 16.—Hand splint to maintain abduction and extension of the thumb, but permitting flexion of the distal phalanx.

portant in order that a strong group of muscles may not overcome a weak group.

In the case of a shoulder, the arm should be abducted to a right angle for most of the day and night, being released four or five times daily and placed in adduction for a few minutes each time. One must be on guard to prevent contracture in adduction and internal rotation.

The elbow should not be allowed to develop a flexion contraction; the wrist should be held in dorsiflexion, and the fingers in the position of grasp. One must guard against pronation deformity. One should be

3. The aluminum and potassium nitrate treatment is the use of this chemical done into a poultice using rolled oats, which is applied to the limb. There are reports of excellent results following this method.

The physical therapeutic measures that may be of value in some cases of osteomyelitis include phototherapy, heliotherapy, the carbon arc lamp and occupational therapy. One must endeavor to maintain muscle tone and counteract atrophy of muscle. Transfusion of blood is indicated in some cases.

ANTERIOR POLIOMYELITIS

In the treatment of anterior poliomyelitis, or infantile paralysis, physical therapeutic measures are indicated in every stage, including the preparalytic, paralytic, subacute and chronic. During the prepara-

FIG. 15.—Double abduction spica cast to be used as a model for making a brace. Patient had bilateral deltoid paralysis due to anterior poliomyelitis.

lytic stage, convalescent serum is probably the most important agent. During this stage the importance of bed positions or bed posture cannot be overemphasized. Proper bed position, including the maintenance of bones and joints in a position of neutral muscle pull, is very im-

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very careful, if the thumb muscles are involved, not to allow deformity to occur.

Bed positions are maintained by means of pillows, boards at the foot of the bed, boards under the mattress, sandbags, salt bags, casts, splints and braces. When the patient is ready for walking, crutches or a special walker is to be used.

The causes of deformity are unequal muscle pull, the effects of gravity and the early use of weakened muscles. The cause of disability is weakness of the muscles. The various physical therapy agents include medical gymnastics, massage, exercises, contrast sprays, neuromuscular reëducation and underwater gymnastics. I have in a few cases used fever therapy; that is, intravenous injection of typhoid vaccine.

ENCEPHALITIS

The important factors to be mentioned here are the prevention of deformity, the correction of deformity and the prevention of disability. The agents used are casts, braces, splints, crutches and canes. Neuromuscular reëducation is very important. Operations on sympathetic nerves are often of value.

Conditions of Mechanical or Static Origin

The mechanical or static group of conditions include: flatfoot, metatarsal depression, pes cavus, knock knee and bowleg.

The function of the foot is to supply an organ of locomotion that is springy, in order to avoid jars to the brain, spinal cord and abdominal organs. Anything that interferes with that function affects the whole body. The harmful effects of foot disturbances are manifested in the foot, leg, knee, back, hip, the nerves and the general health.

The causes underlying foot disturbances are concerned with several factors; viz., heredity, occupation, injury, infection, hard floors, cement sidewalks, asphalt streets, shoes, hosiery, the automobile and other present-day living conditions.

FOOT DISTURBANCES

Abnormal foot conditions comprise four groups: (1) congenital deformities; (2) acquired deformities; (3) diseases of the bones and joints; and (4) tumors.

Congenital defects of the feet—deformities that are present at birth—include absence of toes, supernumerary toes, united toes, overgrowth of the foot or parts of the foot and overlapping and under-riding toes.

Acquired deformities are due to infantile paralysis or other infections, to flatfoot, to depression of the fore part of the foot or metatarsal region and to bunions. Traumatic conditions are due to fracture

and dislocation. Warts, papillomas, hard and soft corns, and circulatory disturbances are acquired conditions.

Diseases of the foot are chiefly tuberculosis, syphilis, osteomyelitis and epiphysitis, or inflammation of the growth-center of the bone. Arthritis or rheumatism may be due to any germ, to metabolic disturbances or to injury.

Posture and Hygiene of the Feet.—SELECTING THE CORRECT SHOES.—The subject of shoes is very important. The first question to be considered is whether shoes should be high or low-cut. Both have eminent advocates, but to my mind the preponderating evidence is in favor of high shoes. Lace-shoes are, as a rule, preferable to button-shoes.

There has been much discussion in regard to the flexibility or rigidity of the shank of the shoe. Individuals without foot troubles may do very well in flexible-shank shoes. Those who have foot troubles, correctable by exercise only, will do well in flexible-shank shoes; but for that large number who need both exercise and support, the rigid-shank shoe is, at least temporarily, of much greater value. The shoe should have a round toe. It should have a medium-width shank. It should be made over a last with a straight inner border. The height of the heel should be within reasonable limits, as both extremes are undesirable, not only because of the effect upon the feet but especially because of the effect upon the back. Shoe fitting is an art too little known. Every individual should change shoes once every day if possible. Shoe-trees or shoe-forms are valuable. Rubber heels, as a rule, are of distinct advantage in minimizing the repeated shocks to the feet, legs, and spine, and to the abdominal and pelvic organs.

GARTERS.—Constriction of the leg is harmful to the circulation. This is true whether the constriction be caused by a circular garter or by rolling stockings in a hard ridge or knot. At the beaches one sees many young girls and women with deep ridges just above the knees caused by circular garters. This causes interference with the return circulation of the blood and produces varicose veins.

Bathing the Feet.—Cleanliness of the feet is of the greatest importance. Ordinary bathing of the feet should be carried out once daily. The soap used should be of a nonirritating variety, and the foot, after being dried, should be dusted with a simple dusting powder. For "tired feet" the addition of small quantities of salicylic and boric acids to the water may be helpful.

Contrast sprays for the feet and legs are administered by sitting on the side of the bathtub and spraying the feet and legs with warm water for one minute and cool water for one minute. Alternate in this manner for ten minutes twice daily. Increase the contrast of the water gradually from day to day. Many prefer to use the warm spray for two minutes, and the cool for half a minute.

Contrast baths, although not so convenient, are of distinct value in improving the circulation of the soft tissues of the foot and leg. To take a contrast bath, obtain two buckets, each large enough to contain both feet. Fill one bucket about two-thirds full of warm water, and the other about two-thirds full of cool water. Sit alongside of the buckets. Place both feet in the warm water for exactly one minute. Remove feet and place in the cool water for exactly one minute. Alternate in this manner for ten minutes, i.e., five minutes in each bucket. Increase the contrast of the water gradually from day to day. If the cool applications are unpleasant, reduce their time to 15 to 30 seconds.

Massage.—Massage of the feet twice daily, spending a few minutes every morning and night, is an excellent tonic. In this massage it is well to use cold cream, cocoa butter, olive oil, oil of wintergreen or an analgesic ointment such as the following:

℞	Olei gaultheriae	4
	Acidi salicylici	4
	Mentholis	4
	Camphorae	4
	Phenolis	1
	Ung. aquae rosae	15
	Lanolin	15

M. et ft. ung. and put in collapsible tube or jar.
Sig.: Use externally for 10 min. twice daily.

Do not rub the skin, but use a deep rotatory movement of the thumbs and fingers.

Hot Applications.—Hot applications, consisting of flannel dressings wrung out of a hot saturated solution of magnesium sulphate, are of value in relieving the ordinary painful foot.

Foot Exercise.—For the young girl's foot there is no exercise of greater value than ordinary ballet dancing, if properly taught. It is good for the feet and for the entire body in developing balance, poise and general muscle tone; but careless methods on the part of the student and teacher may cause arches to break down instead of becoming stronger. Toe-dancing should not be begun, as a rule, before the age of ten years. Ballroom dancing is excellent exercise, but if overdone may produce symptoms of metatarsalgia, i.e., pain in the metatarsal or anterior arch of the foot. Ice-skating and roller-skating are ideal exercises for the feet and legs. While skating on ice, a wide figure-eight webbing or leather strap should be worn over the stocking; if necessary, the ankles may be bandaged, or a skate-strap may be worn outside the shoe, making a figure eight.

For the abnormal foot with weakness of the supporting structures of the longitudinal and transverse arches, a great many special exercises have been prepared. They will be described later.

BUNIONS

When the bursa of the big-toe joint is inflamed, it is called a bunion and corresponds with housemaids' knee. *Hallux valgus* is the term applied to the outward deviation of the big toe. When a bunion occurs in the region of the fifth toe, it is called a "bunionette." There are other conditions of importance in the region of the big toe; viz., rigid big-toe joint, rheumatic or gouty joint and sesamoiditis or inflammation of one or both small bones under the joint.

HAMMER TOES

Hammer toes are deformities that are inherited or acquired. Such a toe is often the site of a corn. Overriding and underriding toes may often be trained to grow into normal position by simple adhesive strapping. Occasionally a toe is so long or so deformed that a surgeon should be consulted as to the proper measure to be taken regarding it.

PAINFUL HEELS

Pain in the heel may be due to a bony spur on its under surface or back, or to bursitis or chilblains in this region. Very often in the two latter cases it is necessary to remove the counter of the shoe, but frequently elevation of the heel in the shoe will afford relief.

For ordinary infections of the foot—as a temporary measure—a hot saturated Epsom-salt solution applied continuously in the form of wet applications, with considerable elevation of the foot, will be of much value.

Concerning the care of the feet at various periods of life, I wish to say:

1. *The infant's foot:* If there is no deformity, care of the infant's foot consists of bathing and the application of a dusting powder. If there is a clubfoot, do not wait until the child is a year old, but have treatment started immediately, even during the first day of life.

2. *The young child's foot:* It is important that the baby's stockings and shoes fit properly. Fat babies should not be encouraged to stand too early, as there is danger of causing bowlegs or knock knees. Stiff-ankle shoes, that is, shoes reënforced with molded leather, are of value in some cases of weak feet. Babies should wear white stockings, but care should be taken to prevent the shrinking of the stockings from frequent washing, as too tight a sock causes foot-compression and produces injurious results.

3. *Care of the feet of the adolescent boy or girl:* From infancy to maturity, proper and abundant exercise of the foot muscles, especially those of the arches, is of the highest importance. One should not wait till the arch is weak, but should aim to strengthen it early and to keep it strong. In buying shoes for adolescents, especially when their feet

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because it provides a point of attachment for the Achilles tendon and *furnishes the initial bearing surface of the foot as it strikes the ground in walking.*

When a foot is in action, it is supported chiefly by muscles, but when standing, chiefly by ligaments.

Foot Posture.—Normally, a plumb line dropped from the middle of the kneecap falls through the middle of the tibia, the middle of the ankle joint and a point between the roots of the first and second toes. If a plumb line is dropped from the middle of the back of the knee, it should be *parallel with and bisect the heel tendon.*

Footprints may reveal a high or a low arch, but they are not of as much practical value as is often supposed.

Fig. 17.—Showing what occurs in case of a depressed arch.

Fig. 18.—Bones of the foot (top view) in normal and flatfoot positions.

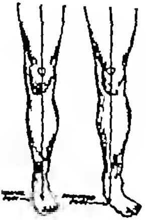


Fig. 19.—Plumb-line test for flatfoot

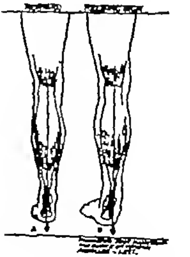


Fig. 20.—Curve of Achilles tendon in flatfoot.

are growing very rapidly or when the feet are unusually long and narrow, care should be taken to see that they are fitted properly.

4. *The adult:* In the care of the adult foot, exercises, massage and contrast baths are important. Here proper fitting is necessary. The fluoroscope, which is in fairly common use at present, is of great value in obtaining proper-fitting shoes. The most important measurement is from the tip of the heel to the middle of the big-toe joint.

5. *The foot of a pregnant woman* must at all times be properly supported, because during this period there is a tendency to a relaxation of the supporting structures due, first, to the altered metabolism and secondly, to the increased weight her feet are required to carry. She must not go around the house barefoot or in bedroom slippers. Her feet should be exercised and massaged twice daily.

6. *In old age,* frequent elevation of the feet and legs is a valuable aid to the circulation of the lower extremities. This treatment is useful for any one past middle life. It may be followed to advantage for an hour every morning and afternoon.

7. *During and after an infection,* such as tonsillitis, influenza, scarlet fever and the like, bedroom slippers should be avoided; great care must be taken to prevent the relaxation of the supporting structures of the foot, due to the toxemia or poison resulting from the infection.

Under the term "occupational foot conditions," we have the foot-troubles of the dentist, policeman, iceman, barber, waitress, nurse, orderly, chauffeur, dancer and soldier. The peculiar circumstances that cause these disturbances cannot be enlarged upon here, but their treatment comes under the general rules laid down in this chapter.

Standing causes more strain on the arches than walking, because it furnishes no interval of relief from weight-bearing. Many persons can walk miles without tiring but suffer considerably if compelled to stand in a street car or elevated train for thirty minutes.

Physiology of the Foot.—The physiology of the foot consists chiefly of the mechanics of a member whose function is twofold: first, weight-bearing, and second, flexible locomotion.

Normally, a plumb line dropped from the middle of the kneecap falls through the middle of the mortise-bone of the ankle and through a point between the bases of the first and second toes. This is known as the weight-bearing line. In a normal foot, a line drawn through the middle of the great toe and continued backward passes through a central point in the heel.

Two bones of great importance are the astragalus and os calcis. The former is important because it is the mortise-bone between the leg and the foot. The astragalus articulates with the tibia, fibula, scaphoid and with the os calcis in three places; it cannot move itself because it has no muscle attachments; it is subjected to more superincumbent weight than any other bone in the body. The os calcis is important

the inner surface (the tibials) are stretched and lose some of their power. It is a physiologic law that when a normal tendon is overstretched it loses power and, when allowed to contract, it promptly does so, thereby usually gaining in strength. There is gaping of the

FIG. 11.—High degree of pronation or flat feet. Note large exostoses of the first metatarsal heads with bunions and hallux valgus.

bones on the inner border of the foot and compression of the bones on the outer border.

Careful examination often reveals that the general muscular condition of a child suffering from flatfoot is below par; there may be a generalized muscle weakness. Knock knees are more common than bowlegs. A round back is frequently present. The mother says the child is awkward, that it does not walk properly and that the ankle bones protrude. There seems to be a bone displaced; the ankles "interfere," and the child complains of early fatigue, has "weak ankles" and runs the shoes over unnaturally. The child does not want to run

FLATFOOT

The subject of flatfoot can be discussed under flatfoot in children, in infants and in adults. The early treatment is very important and it includes rest, support, supination, exercises, massage, contrast sprays, modification of the shoes and inserts in the shoes. Many operations have been devised for the correction of flatfoot, including those of Perthes, Gleich, Lord, Miller, Clark and Hoke.

The subject of flatfoot among infants and children is becoming more and more important. The defect has not been given proper consideration. Heredity is undoubtedly a very important factor in causing this malformation, and in my experience the paternal parent is usually the one involved. The various periods at which feet should be inspected are: at birth, six months, one year, two years, three years, four years and adolescence. Naturally, one would anticipate more anatomic deviation of this kind in the negro, but it does not appear that the disability or discomfort is more common in that race. Certain disturbances in intra-uterine life might explain some cases; for instance, unusual foot-position of the embryo might cause it. Any condition causing weakened musculature may produce flatfoot. I have had cases following diphtheria.

There is a definite type of weak, pronated or flatfoot that appears coincident with adolescence, in long, slender, rapidly growing feet, especially in girls. Focal infection, such as tonsillitis, may cause flatfoot by a toxic relaxation of the supporting structures, unprotected by proper prophylactic measures. These infections might cause a toxic arthritis or rheumatism, with resulting rigid flatfoot deformity. Such cases are quite resistant to treatment.

Obesity causes flatfoot in two ways: first, by the strain of an excessive load, as there is usually a disproportion between the weight to be carried and the size and power of the feet and lower legs; second, by glandular disturbances such as are most likely to be seen in overweight boys and girls. Knock knees are often found in these children.

Injury may result in a flatfoot. Infantile paralysis is a frequent cause. There may be severe mechanical effects on muscles, ligaments and capsules of the joints and bones.

Anatomic Considerations of Flatfoot.—One of the mechanical changes in flat feet is found to be the inward and downward rotation of the upper border of the heel bone. Another is the lateral attachment of the heel tendon. This may be the cause or the effect of the mechanical disturbance.

The upper border of the mortise-bone is tilted medially, carrying the inner border lower than the outer so that the weight strikes a glancing instead of a square blow. Mechanically this is injurious. The peroneal tendons on the outer surface of the leg and ankle contract. Those on

correct other conditions such as knock knees or bowlegs. The means to these ends include proper shoes, exercises, massage, contrast foot-baths, resilient pads, plaster-of-paris casts and operation.

The child should be taught to walk with the feet parallel or toeing-in slightly. It should come down on its heels, tilt its weight to the outer borders of the feet and come up on the toes with a spring.

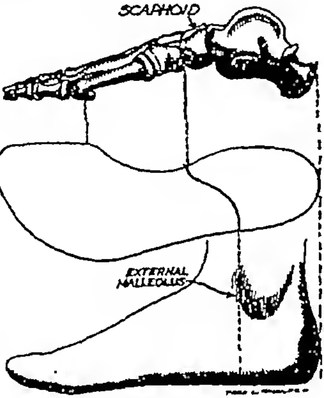


FIG. 15.—Illustrating inner and outer border measurements of H. O. Thomas orthopedic heel.

SHOES.—Only in extreme cases will it be necessary to have the shoe made to order; but it should be a well-fitted lace-shoe. The writer always recommends shoes that come up around the ankle; but many good orthopedic surgeons recommend low shoes as giving more freedom to the ankles. Some authorities permit low shoes for healthy or only slightly weakened feet. The most important measurement is from the back of the heel to the middle of the big-toe joint, which should be opposite the point at which the shank joins the ball of the sole. Next, the shoe must grasp the heel of the wearer; it must not be too wide at the heel and through the shank, and should allow for the growth of the foot. The use of a fluoroscope in fitting shoes is of great value.

Flexible-shank shoes are indicated when the patient needs only exercise; but most of the patients brought to the orthopedic surgeon

and play. Pain is usually absent because the foot is flexible; but if rheumatism should develop, decreasing flexibility, a rigid flatfoot would result in a disabling deformity.

On viewing the child from the front, one sees the flattening of the arch and the outward deviation of the fore part of the foot. A plumb line dropped from the middle of the patella falls inside the normal point. A rear view reveals the medialward curving of the heel tendon. A plumb line dropped from the middle of the popliteal space is not parallel with the heel tendon. The heel is flattened and rotated, in some cases producing the "heel of the ape." The prominence of the region just below and in front of the inner ankle bone (the scaphoid) resembles another ankle bone. It is possible to have a flatfoot on one side and a clubfoot on the other.

A B C

FIG. 22.—A and B, incorrect standing posture; C, correct posture.

The value of footprints has been overestimated from the viewpoint both of diagnosis and of progress. The print of the new-born infant is misleading in that it usually looks flat. As a matter of fact, the foot of a new-born infant, if cross-sectioned, will reveal a definite bony arch obliterated by a fat pad. One may find a foot with a high arch but in a position of strain.

The chances of recovering from flatfoot are very good, depending on how well the patient, parent or governess carries out the treatment. In the rigid type the duration of treatment may be long.

Treatment.—The objectives of treatment are to teach proper walking, to increase the power of the supporting structures, to stimulate the local circulation, to correct the flattening and restore the arch, and to

quite satisfactory for preliminary wear. It may be discontinued when the feet improve in strength.

The modification of the shoe consists chiefly in the application of a Thomas heel, a method devised many years ago by an orthopedic surgeon of Liverpool, and one that has been altered at times but never improved. Each child must be measured for this heel. There are four

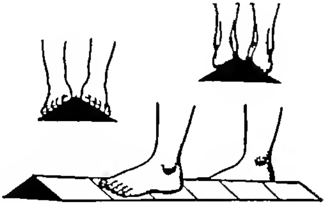


FIG. 17.—Supination board. Above: front and rear views. Below: side view.

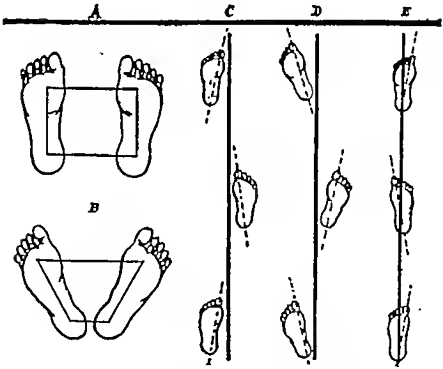
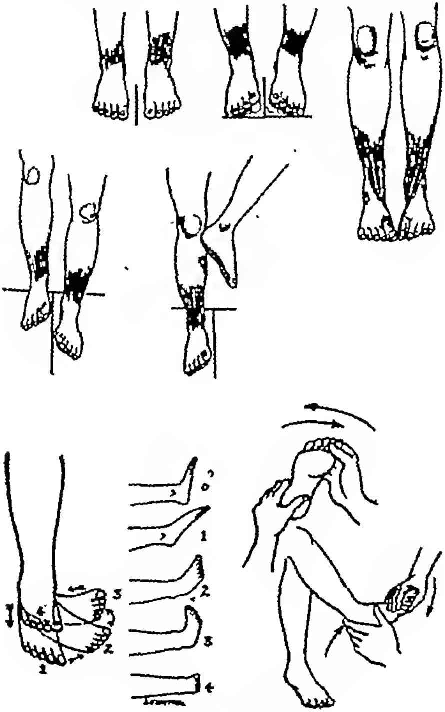


FIG. 18.—Right and wrong foot postures. A, correct standing position. B, military standing position—incorrect. C, correct walking position. D, military walking position—incorrect. E, Indian position, walking. (Ellis.)

need both exercise and support, and the latter need is not supplied except by a rigid or semirigid shank. The problem is like that of keeping a bridge from sagging in the middle. The insertion of a corrugated metal shank changes a flexible-shank shoe into one that is



FIGS. 24, 25, 26—Longitudinal arch exercises.

dimensions: the inner border height, the outer border height, the inner border length and the outer border length. The imitations so frequently seen of this heel are very poor. The function of the heel is to compel the child to walk over the outer border of the foot, and when properly made it forces his ankle into the correct position. Reënforced uppers for "weak ankles" are used occasionally as a temporary measure. It is important that the leather reënforcement be carefully molded over the ankle bones, or pressure-areas will result.

Gymnasium shoes should be worn for gymnasium use only. They should include the ankle and have resilient pads inserted. Ballet slippers should not be worn except while dancing. They, too, can be padded.

The child must not go barefoot except in the sand or in soft ground. During convalescence from any illness, it is very important that the child's feet be supported at all times during weight-bearing, because it is a period of relaxation of the supporting structures of the arch. One should never permit bedroom slippers to be worn.

Exercises to Correct Flatfoot.—Exercises are the most important factor in the treatment. They are active and resistive, and should be carried out twice daily in bare or in stockinged feet. Exercises must be done slowly, and the feet should never be allowed to "come down with a bang." A great many special exercises have been described. Some of the most valuable are these:

1. Stand barefoot with the feet parallel and about two inches apart, straddling a seam or a line in a rug. On the count of 1, force the feet apart without actually allowing them to move apart, thus throwing the weight on their outer borders; on the count of 2, allow them to roll in slowly but not all the way. This is repeated ten times at first, with a gradual daily increase that may run up to 100.

2. Same as number 1, except that the two big toes are held together and on the floor.

3. Straddling a seam in the rug or a line on the floor, walk across the room with all the weight on the outer borders of the feet and the toes curled downward and inward. Make the round trip five times.

4. This is the same as number 3, except that one raises one foot so that it is opposite the other knee and walks across the room in that way, using the so-called "ostrich-step." Weight must at all times be borne on the outer border of the foot.

5. The feet are held parallel, and the knees are maintained in a straight position. The knees are then rolled outward, which automatically causes the longitudinal arches to rise (Lowman). This is repeated from 10 to 25 times.

6. Rise on the toes, tilt the weight to the outer borders and come down in two counts. This should be done from 10 to 25 times.

7. Use a supination board about six inches high and eight feet long, its sloping sides being at the angle of an isosceles triangle. The child

A B C

Fig. 29.—Illustrating standing exercises for flat feet. A, exercise No. 1; B, exercise No. 2 as seen from the front; C, exercise No. 2 as seen from the rear.

A B

Fig. 30.—Illustrating walking exercises for flat feet. A, exercise No. 3; B, exercise No. 4.

10. Older children and adults can perform this exercise as follows: The left foot is turned inward and upward and held in that position, firmly. The right foot is placed against the left and attempts to force the left outward, which effort the left foot resists. Then the relation of feet to each other is reversed. After each of these exercises the subject relaxes his feet.

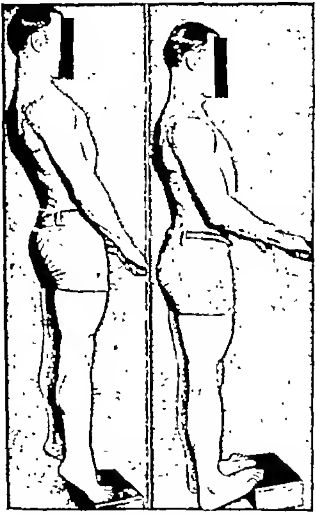


Fig. 32.—Exercise for stretching the Achilles tendons. (Lewin, J.A.M.A., 88, April 9, 1927.)

Stretching the Heel Tendon.—The following are a few special exercises for stretching the Achilles tendon:

1. Simply walking on the heels across the room five times.
2. From the standing position with the feet parallel, the patient squats down to the position of sitting on the heels, maintaining the heels and toes on the ground. This is done in two counts.

walks the length of the board three or four times as one would walk on the ridge of a housetop.

8. The subject is seated on a chair with legs crossed, so that the raised foot can relax. He then holds the foot at right angles with the leg and not turned in or out. The exercise is done in four counts. On the count of 1, the foot is allowed to relax into the position of toe drop. On the count of 2, it is swung in; on the count of 3, it is

Fig. 31.—Exercise No. 10 for flat feet.

forcibly pulled upward; and on the count of 4, it is brought back to the starting position, describing a half-circle. This is performed 10 times at first and may gradually be increased to 25 times.

9. This is a resistive exercise. The subject sits on a table, and a second person sits on a chair. The subject forcibly swings his foot inward and upward and holds it in this position with all his power. The second person attempts to swing the foot outward and downward. This effort on the part of the second person is resisted by the subject. The exercise is carried out from 10 to 25 times. At no time should the second person use as much power as the first.

in the foot; therefore, very little space is required. They are inserted directly into the shoes and held by means of a special glue.

A Goldthwait figure-of-eight leather ankle strap is of some value. Adhesive strapping is often beneficial, especially for injured feet. Plaster of paris is necessary in some cases and is usually better than braces for short periods. Some orthopedic surgeons recommend plaster over comparatively long periods, in an attempt to cause a certain degree of rigidity or stiffness in an overcorrected position. Braces may be required.

Operation is rarely indicated, except for rigid flat feet, in which type forcible manipulation under anesthesia and the application of a corrective plaster cast are of great value. Occasionally the tendons must be operated upon. Lengthening of the heel tendon is necessary in so-called "muscle-bound" feet, because patients suffering from this condition are unable to perform the exercises properly, owing to the structural shortening of the tendon.

Other operations are those performed on the bones and tendons.

DISTURBANCES OF THE METATARSAL ARCH

The subject of metatarsal-arch disturbances—popularly known as one type of "fallen arches"—is attaining the increasing importance it deserves. For a long period it was a general conception that nearly every condition occurring in this region was a "Morton's toe." The term *metatarsalgia*, meaning pain in this region, designates a symptom and does not fully describe the condition.

The metatarsophalangeal joints are simple ball-and-socket joints. Like other joints, therefore, they are subject to stress, strain, injury, growth disturbance and infection. The muscles and tendons of this region are important.

The skin of the plantar surface of this area is unusually thick. The chief functions of the metatarsal regions are to afford stability in locomotion, to permit spring and resilience to the step and to relieve jars on the body, especially on the spine and the central nervous system. The transverse arch is highest near the midportion of the foot and gradually lowers toward the metatarsal heads. Considered from the mechanical point of view, the metatarsal arch is curved in two directions, laterally and from front to back. What is usually referred to as the metatarsal arch is that structure formed by the metatarsal heads and is the true transverse arch. This mechanical structure protects the nerves, vessels, muscles, tendons and ligaments of the sole of the foot from injury.

The transverse arch is maintained chiefly by the transversely directed ligaments. When the transverse arch is properly maintained, the anterior pillar of the longitudinal arch rests on the heads of the first and fourth metatarsal bones only; that of the fifth also presses on the ground in many cases, especially when more weight is borne on

3. The patient stands facing the wall with the toes 28 inches from it. The toes are placed together and the heels as far apart as possible. With the hands placed against the wall and the heels remaining on the floor, the entire rigid body is allowed to fall forward as far as possible, by bending the elbows, and to remain in this position a few seconds before returning to the starting position. This is done in two counts, each about ten times.

4. The apparatus for this exercise consists of two handles fastened to the wall and a heavy wooden block 3½ inches high, 12 inches wide and 7 inches in depth, fastened to the floor. The patient faces the wall, standing with the anterior portions of both feet on the block and holding on to the handles. On the count of 1, the heels are allowed to touch the floor, the body being kept parallel with the wall. On the count of 2, the return is made to the starting position. The exercise is carried out from 10 to 20 times, this number being attained gradually.

5. The patient stands with the anterior ball of each foot on a stair, facing upward and holding the balustrade, and allows the heels to drop. He then returns to the starting position.

Other Exercises.—Ballet dancing is excellent exercise because of the foot-training, although much of it is very hard on the longitudinal arch at first. There are, indeed, some children for whom it is detrimental until their feet have been strengthened by the treatment outlined here. Ballet dancing may be started at the age of 4 or 5 years; toe-dancing should not be started, as a rule, before the age of 8 or 10 years.

Swimming is very good exercise. Roller-skating also is good, and so is ice-skating, but both may be harmful at first unless proper precautions are taken. The child should wear a wide figure-of-eight webbing or leather strap outside of the shoe. Kiddy-cars may be injurious under certain circumstances.

Massage of the feet and legs should be given twice daily, using olive oil or cocoa butter. The movement should be deep and rotatory. In the case of painful feet in older children, an anodyne ointment should be used. Contrast foot bathing should be prescribed for older children.

Support for the longitudinal arch is obtained by means of felt or rubber pads. These afford a resilient support and thereby increase the spring of the gait. They are preferable to rigid supports, such as those made of metal, celluloid or leather. Metal arch-supports prevent the supporting structures from growing stronger.

I have long since discontinued the use of leather insoles, because they confuse the shoe-fitter, who cannot judge accurately the amount of space to be allowed. He should be instructed to fit the foot accurately without allowing for anything. The pads go into natural hollows

proper shoes and incorrect shoe-fitting. Short stockings and the pulling of stockings too tightly are additional factors. Heredity may be important, especially in the rheumatic and "high instep" pes cavus cases.

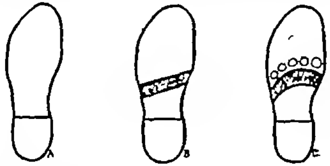


FIG. 35.—Modification of shoe for correction of anterior arch depression. A, sole of a proper walking-shoe. B, position of leather metatarsal bar, ⅜ inch thick and 1 inch wide. C, position of metatarsal crescent and relation to heads of metatarsals.

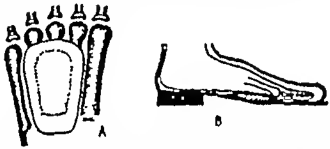


FIG. 36.—Using a felt pad for a depressed metatarsal arch. A, position of beveled pad with relation to metatarsal arch. B, position of pad in shoe.

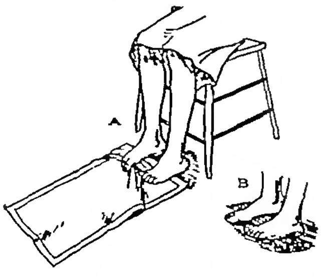


FIG. 37.—Towel exercise for metatarsal arch disturbance.

the foot. If the transverse arch yields, the heads of the intervening metatarsal bones receive undue pressure and callosities develop under them. When the muscles of this region are paralyzed or weakened, the toes assume a position of "clawtoe" and the normal gait is interfered with. Conversely, if the toes are forced to assume a position of

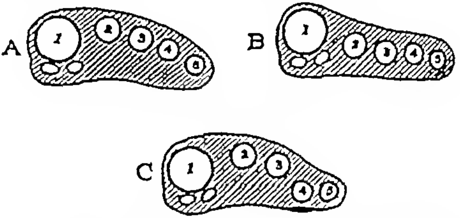


FIG. 33.—A, normal position of metatarsal heads and sesamoid bones. B, depressed metatarsal arch. C, depression of fourth metatarsal head, with production of callosity.

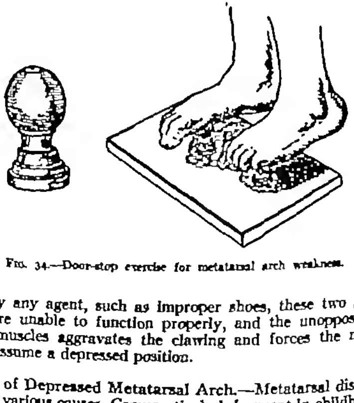


FIG. 34.—Door-stop exercise for metatarsal arch weakness.

clawing by any agent, such as improper shoes, these two groups of muscles are unable to function properly, and the unopposed action of other muscles aggravates the clawing and forces the metatarsal heads to assume a depressed position.

Causes of Depressed Metatarsal Arch.—Metatarsal disturbances are due to various causes. Comparatively infrequent in childhood, they are very common in adults. Women suffer from them more often than men, undoubtedly because they are so frequently the victims of im-

cation of an anodyne lotion, is used in conjunction with hot applications and elevation of the feet.

Shoes must be of straight last, round toe, medium-width shank and moderate-height heel. The shank should be rigid if there is an accompanying disturbance of the longitudinal arch. The fitting of the shoe is very important. Even custom-made shoes are often too short. The shoe may be modified by the addition or insertion of a metatarsal bar

FIG. 38.—Metatarsal elastic band.

or, preferably, a crescent. Into the shoe there should be inserted a felt pad properly shaped and beveled to support the depressed structures. This pad may be applied directly to the foot temporarily, secured by means of a resinous glue and strips of adhesive plaster or by means of a simple elastic metatarsal cuff, which in itself has some value in supporting the arch laterally. A laced leather cuff is preferred by some orthopedic surgeons. An adhesive compression band often affords considerable temporary relief.

The felt pad is usually inserted directly into the shoe, being secured by means of glue. An insole is not essential. Because it is not physio-

Rheumatism is an important cause of metatarsalgia. Infections of various types contribute a fair share of these cases. The infection may be local or focal, such as infected teeth, tonsils, sinuses and abdominal or pelvic organs. Toxemia, as from pregnancy or from an infection such as influenza, is a causative factor. Static disturbances, such as prolonged standing on hard floors, predispose to arch troubles. Injuries of various sorts are very important, such as the sprain or strain seen in the chauffeur's foot or in the dancer's foot, especially in toe-dancing. The injury from shoes has been mentioned. Injury by falling objects or being stepped on by another person or by an animal may cause metatarsalgia. I have seen a nurse who developed metatarsalgia following the accidental shooting off of all her toes. I have also seen a physician who had metatarsalgia following a septic infection of the metatarsal region as a result of the piercing of his shoe by an infected knife which dropped during an operation. Fractures, dislocations and burns, both by heat and by chemicals, may result in metatarsalgia; the same is true of a "high instep," sometimes appearing at puberty; disturbances of the circulation; frost-bite, chilblains, trench foot, and soft corns.

There is depression or inversion of the arch, which normally is convex above. This produces pressure on the nerves and relaxation of the supporting structures. Warts and soft corns (usually between the fourth and fifth toes) are common.

Symptoms.—The symptoms of metatarsal arch disturbances are pain, rigidity and, at times, spasm of the muscles and contracture of their tendons. The physical conditions of metatarsal depression are the inversion of the arch, callus formation, sensitiveness and tenderness, usually due to periostitis. Every schoolboy knows that if he can grasp another boy's hand, depress the knuckles and exert lateral compression, he can cause pain. An analogous situation is found in a depressed metatarsal arch.

Roentgenograms are usually not necessary in making a diagnosis, although they are always desirable. They reveal the depression on side view, and also show bunions, "bunionettes" (overgrowth of the fifth metatarsal heads) and the position and integrity of the two sesamoids under the big-toe joint.

Methods of Treatment.—The result of treatment depends on the coöperation of the patient. The course is often long. The treatment of the usual type of metatarsalgia consists of local and general measures, the latter being removal of foci of infection and the correction of metabolic, hygienic and dietetic disturbances. The local treatment consists of relief from inflammation or irritation, proper shoes and shoeing, metatarsal support and the physiologic restoration of power of the supporting structures of the arch.

Relief from inflammation may be accomplished by rest and relief from weight-bearing. In the severe cases, rest in bed, with the appli-

they are screwed into a board about 14 inches long, 8 inches wide and 2 inches thick. The centers of the door-stops should be 6 inches apart.

The board is placed on the floor, and the patient sits on a chair in front of it. Each foot is placed on a door-stop with very slight pressure *just behind* the metatarsal bones. On the count of 1 the toes are forcibly curled down, and on the count of 2 they are allowed to relax slowly. This is continued until one has counted 200. (This number should be attained gradually.)

Towel Exercise.—The patient sits in a chair. A large hand-towel is spread on the carpet, with the narrow edge facing the patient. Both feet are placed on the towel so that half of each foot is on the towel. The towel is grasped with the toes of one foot, then with the toes of the other. As the toes of one foot grasp, those of the other foot relax. This is continued until the entire towel is under the feet.

Golf-ball Exercise.—A golf-ball is placed on the rug and rolled under the metatarsal arch for one minute. Then it is picked up with the toes of one foot and placed under the toes of the other foot, and the exercise is repeated for another minute. The patient alternates in this manner six times.

Marble Exercise.—Marbles of various sizes are placed on a rug. The patient sits in a chair and picks up marbles with her toes.

Pencil Exercise.—A round pencil is placed on a hard floor, and, by means of the curled down toes, the patient pushes and pulls the pencil around the floor with short, quick movements.

Arch-supports.—There has been much discussion concerning metal arch-supports. It is the writer's belief, based on some years' experience, that metal arch-supports, because they act as props or crutches, are of doubtful value. While they brace or hold up an arch, they do not increase the power of the supporting structures of the arch; in fact, the effect produced is generally one of weakening, and they are therefore not recommended. Arches can be held up by resilient material which not only supports but tends to increase the strength of the supporting structures of the feet.

Diathermy, negative galvanism and sinusoidal current are helpful adjuvants in the treatment of metatarsalgia. Plaster-of-paris casts are frequently required. Less frequently is operation necessary.

Among the allied conditions found are profuse perspiration, ringworm, hard and soft corns, calluses, warts, bunions, "bunionettes," hammer toes, contracted tendons, circulatory disturbances and a stiff big toe.

ANKLE SPRAINS

A sprain is a stretching or tearing of the muscles, tendons, ligaments or capsule of the joint. A fracture is a break of a bone. There is a saying that a sprain is worse than a broken bone. This is untrue. Many sprains, however, are improperly treated because the roentgen-

logically correct to compress the delicate foot muscles between the rigid bones above and a rigid object below, I practically never use a metal plate to support a depressed metatarsal arch, depending entirely on the resilient support of the felt pad. The patient's hose should be long enough and must not be drawn too tightly. Massage of the feet twice daily with a special ointment is very valuable. Contrast foot-baths afford the feet a very valuable tonic.

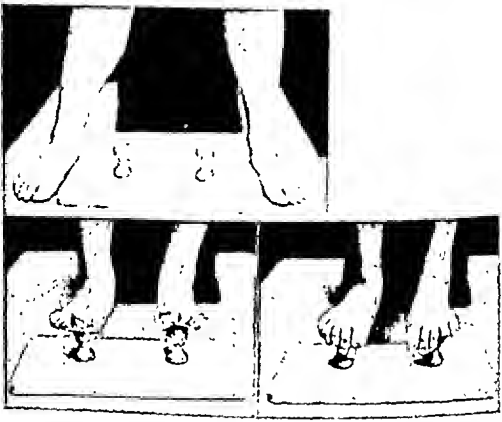


FIG. 19.—Door-stop board used in performing exercises to strengthen the supporting structures of the transverse or metatarsal arch. A, the door-stop board; B, feet resting on door-stops preparatory to performing the motion illustrated in C—namely, curling the toes downward over the knobs.

HELPFUL EXERCISES.—Special exercises are of the greatest value in increasing the power of the supporting structures and the flexibility of the metatarsal arch. Numerous exercises have been described and recommended. The following have been found of much value. Each exercise is done with the bare feet twice daily:

Door-stop Exercise.—Two old-fashioned door-stops, obtainable at the hardware section of one of the 5-and-10-cent stores, are prepared for use by removal of the rubber tips with a pair of nippers. Then

There is still a divergence of opinion concerning the immediate treatment of a sprained ankle. The following is a good routine:

1. Give it absolute freedom from bearing weight.
2. Elevate the entire limb.
3. Apply a snug gauze bandage over sheet-wadding or cotton.
4. Apply ice bags.
5. Have a roentgenogram made and strap the ankle with adhesive or, if the sprain is severe, apply a plaster-of-paris cast.

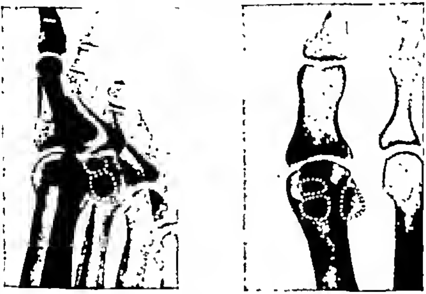


FIG. 41.—Split sesamoid bone, producing pain under big-toe joint.

FIG. 42.—Proper shoe for lady after bunion operation.

ogram does not reveal a fracture or dislocation; the condition may then become serious from lack of sufficient attention. Oftentimes the best treatment for a sprain is the application of a plaster-of-paris cast for a few days, combined with the elevation of the foot and leg; then the application of a firm adhesive strapping. After seven to fourteen

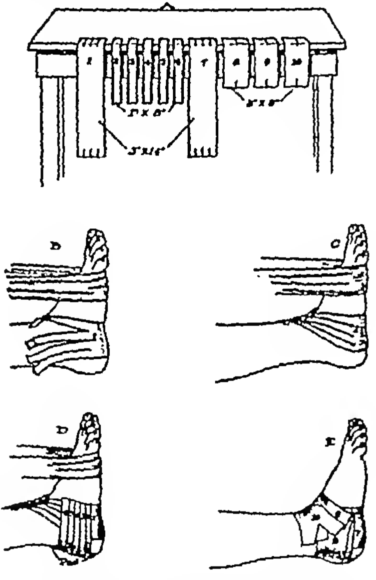


FIG. 40.—Adhesive strapping for sprained ankle.

days an elastic anglet or resilient bandage is worn. This is removed morning and evening for massage and contrast baths. If diathermy or radiant heat can be given, it will hasten recovery. Passive movements of the joints by a second person and active movements but no weight-bearing by the patient are very important and should be carried out within the limit of pain.

FIG. 43A.—Third and fourth, or last, stages of ankle strapping.

FIG. 44.—Ankle and leg strapping to protect the Achilles tendon and support the calf.

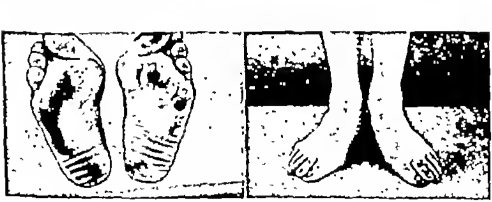


FIG. 45.—Bunions, hallux valgus and flat feet.

FIG. 43.—Lewin's method of adhesive strapping of ankle. 1, Adhesive cut in strips and cut as described in text. 2, Holding foot in proper position by means of bandage guy ropes. 3, Application of preliminary strips of adhesive. 4, Strapping half completed.

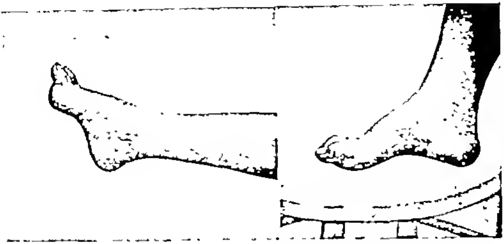


FIG. 48.—Pes cavus, or hollow foot. Note the high longitudinal and low transverse arches.

and determine the amount of blood going to the tissues. They are not under the control of the individual. They are affected by such poisons as alcohol, tobacco, lead, arsenic and infections.

RIGID TOE JOINT

Hallux rigidus, or rigid big-toe joint, whether of the flexed or the straight variety, may be relieved by the insertion of a thin strip of steel the entire length of the sole of the shoe, in order to prevent movement at the big-toe joint. True gout is not seen very often at present, but there is a very definite rheumatic condition occurring in the region of the big-toe joint that is either caused or aggravated by disturbances of metabolism, especially the metabolism of meat, fish and eggs. Sesamoiditis is a painful condition involving the under surface of the big-toe joint. The sesamoids in the tendons are subject to much stress and strain, especially in stepping or jumping from a height or in dancing. Often the roentgenogram will reveal a division of a sesamoid resembling fracture. Many of these are developmental peculiarities which are especially susceptible to injury. Usually relief from weight-bearing affords comfort, but occasionally removal of the bone is necessary.

HALLUX VALGUS

Bunions are due to bursitis, or inflammation of the bursal sac, in the region of the big-toe joint. Hallux valgus is the outward deviation of the big toe with the formation of an overgrowth of bone (exostosis) at the big-toe joint. The chief causes are heredity, short or pointed shoes, short stockings, infection or injury. The most important prophylactic, or preventive, measure is proper shoes and shoe-fitting from infancy to old age.

6. Crutches should be used.

7. The foot should not hang down for long periods. The guides, in this respect, are swelling, blueness and pain.

The arteries of the limbs have sympathetic nerves in their walls. These nerves control the size of the openings to the smaller vessels

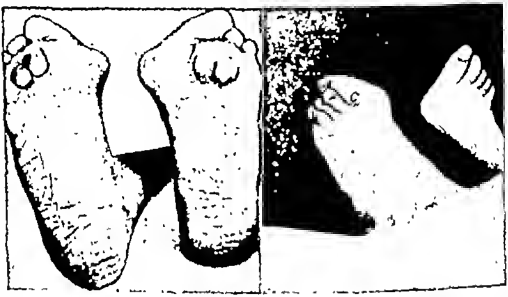


FIG. 46.—An extreme case of bunions, hallux valgus, calluses and corns.

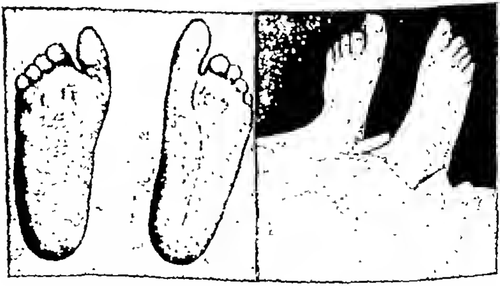


FIG. 47.—The same feet as shown in Figure 46 after operation designed by Dr. John L. Porter [Porter, Surg. Gynec. Obst., 26:460 (April) 1918.]

HOLLOW FOOT

Pes cavus, or hollow foot, is an exaggeration of the longitudinal arch with depression of the metatarsal arch. There is usually limitation of dorsiflexion.

Heredity is an important factor. I have seen three members of one family with this deformity. High-heel shoes, excessive use of the calf muscles (sometimes seen in dancers), infantile paralysis, neuritis in childhood, gout, rheumatism, injury and habitual posture of the foot, such as is seen in compensation for a short limb, are other factors in causing this condition.

CALCANEAL SPURS

Etiology.—It is the customary teaching that all calcaneal spurs are gonorrheal in origin. This is grossly wrong. The various factors are as follows: First, focal infections with the ordinary cocci, gonococci and spirochetes; second, metabolic disturbances, especially of gastro-intestinal and gallbladder origin (I have seen a large number of cases in which the metabolic factor either was most important or was an element in the exaggeration of other factors, possibly in the nature of a sensitization process); third, trauma, due to injury and improper shoes; fourth, static, due to flat feet; and fifth, a pathologic condition of the plantar fascia—a short plantar fascia pulling on its attachment to the os calcis.

Anatomy.—The plantar fascia takes its origin from the tuberosity of the os calcis. If pressure is applied to this area or if the plantar fascia pulls on its attachment, there will result a slight separation or pulling off of the periosteum at this point. Owing to the stimulation of trauma or infection, or both, osteogenesis occurs more actively and a vicious cycle is established, i.e., as the periosteum separates, new bone formation occurs and a spur results, due to the proliferation of the osteogenic layer of the periosteum.

Symptoms.—The symptoms are pain, tenderness, swelling and limp. The onset is usually gradual except when due to an infection, such as acute arthritis, when it may be very acute. The pain and tenderness are usually along the internal lateral border of the os calcis or at the attachment of the plantar fascia. The roentgenogram may or may not reveal a bony spur, depending on the duration of the pathologic condition and the density of the spur. Many very painful heels are seen, roentgenograms of which reveal no spurs.

Diagnosis.—The differential diagnosis rests between osteoma, flat-foot and arthritis.

Prognosis.—The prognosis of complete relief is good if the spur is the only cause of trouble. If there is an arthritis of the foot, removal

FIG. 49.—Well-developed calcified spur causing no symptoms.

FIG. 50.—Very slight spur formation of os calcis causing intense pain and sensitiveness in the heel.

It is a fairly common condition, occurring usually in boys between the ages of nine and thirteen years. The probable cause is concerned with two factors: local injury, either external or internal, and local circulatory disturbances affecting the growth center during a critical period in its development. The treatment consists of immobilization in plaster of paris and relief from weight-bearing, plus general hygienic considerations. The chances of recovery are excellent.

There may be a history of injury, but the initial causes differ. The child might have been running on hard pavements, wearing sandals or tennis shoes. The onset is gradual. A limp is usually the first symptom, and it may or may not be accompanied by pain. The pain is dull and localized to the affected area. It is less marked while shoes with heels are worn. Pressure by the shoe aggravates the pain. Swelling is present. There may be obliteration of the normal outlines, due to thickening of the tissues. Signs of acute infection are not prominent. Tenderness may be present over the posterior portion of the heel for weeks or even months. The child does not permit stretching of the heel tendon, which accounts for the toe-drop position of the foot. There is a disinclination to complete the full step while walking. Flatfoot may be present.

Roentgenograms made in two directions reveal irregularity of the bone with thickening in all directions. Clouding, irregularity or partial obliteration of the epiphysial space may be observed.

Other conditions occurring in this area are:

Achillobursitis, or inflammation of the bursa between the Achilles tendon and the os calcis, reveals a more superficial and localized inflammation. Roentgenograms of the bone are normal.

Tenosynovitis of the Achilles tendon is characterized by pain referred to the tendon and by palpable grating, crepitus or roughness on movement. The roentgenogram is negative.

Bursitis between the heel tendon and the skin is a superficial inflammation, usually the result of pressure by the shoe.

The prognosis in apophysitis of the os calcis is excellent if proper orthopedic treatment is instituted. The duration of the condition may vary from a few weeks to several months. The trouble may recur as a result of overactivity or injury.

Treatment.—The treatment of apophysitis is simple. The objectives are to relieve the Achilles tendon of strain and to prevent weight-bearing on the os calcis. The most satisfactory treatment of a severe case consists of the application of a plaster-of-paris cast extending from the toes to just above the knee, in such a manner as to hold the foot in a slight toe drop—thus relaxing the pull of the calf group muscles—and the knee slightly bent. Two crutches and a two-inch block under the heel and sole of the opposite shoe aid in locomotion.

of the spur will not give sufficient relief. Most patients can be made comfortable without operation; others are not relieved by operation. There may be recurrence of symptoms and spur formation in the same or the opposite foot.

Treatment.—NONOPERATIVE.—The etiologic factors, the residue of a gonococcus infection, infected tonsils or teeth, should be treated if they can be found. The gastro-intestinal condition should be relieved if possible. Weight-bearing should be discontinued, and bed treatment, consisting of the application of an anodyne lotion plus fomentations, should be given. An excellent anodyne lotion is described on page 7.

Directions for the use of this lotion are as follows: The entire foot and ankle are covered by four layers of gauze saturated with the lotion and enclosed in oiled silk or rubber sheeting. Hot fomentations of strips or pads of flannel are wrung out of hot water, about six layers wrapped around the impervious layer, and another sheet of oiled silk applied. A hot water bag is placed at the side or under the foot and everything enclosed in a Turkish towel. The foot should be elevated. A small amount of lotion is added and the fomentations renewed three times daily.

After all pain and most of the sensitiveness have disappeared, plaster-of-paris casts should be applied. Proper shoes are prescribed after casts have been worn from two to four weeks. Shoes should be high, laced, of straight last, round toe and medium-width shank, rigid at first. Felt pads are inserted in the shoes to relieve weight-bearing on painful areas. The heel of the shoe should be entirely removed and a low rubber heel substituted. Roentgenotherapy is advocated by some. I had a patient who pounded his heels with the flat side of a hammer daily for many months and experienced relief.

OPERATIVE.—Operative treatment consists in the removal of the spur. Operative trauma often stimulates osteogenesis, especially if the causative agent is still operating. The size of the spur is not the determining factor. The removal of the spur is accomplished by means of a chisel or osteotome and mallet. Plaster casts are applied and should remain in position for about ten days.

POSTOPERATIVE.—Postoperative care consists in the relief from weight-bearing by means of proper shoes into which are inserted weight-relieving felt pads. The diet should be considered very important in cases of metabolic disturbance, and these cases are very common. As a rule, meat, eggs and fish are contraindicated. Diathermy is beneficial for an accompanying arthritis.

APOPHYSITIS OF THE CALCIS

Apophysitis of the os calcis, first described by Sever, is an inflammation of the cap-like epiphysis of the posterior portion of the heel bone.

Upper Arm.—Conditions of the upper arm are chiefly rupture of the biceps tendon, posttraumatic, such as fractures and dislocations, rupture of muscle, rupture of tendon, myositis and brachial neuritis. The chief measures of value are radiant heat, massage and diathermy.

Elbow.—Conditions around the elbow that are benefited by physical therapy are chiefly arthritis, periarthritis, bursitis, posttraumatic conditions, such as fracture, dislocation, fracture-dislocation, epiphysial separation, rupture of the attachments of the flexor and extensor tendons. The most valuable measures are rest, radiant heat, massage, dia-

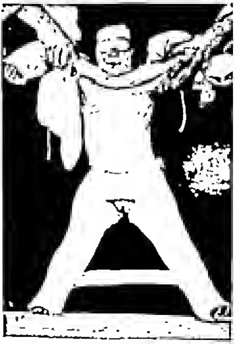


Fig. 51.—Bowlegs (genu varum) in a child of 3 years. Multiple osteotomies and double spica cast.

Fig. 52.—Double plaster-of-paris spica to maintain correction in a child who had severe bowlegs which were corrected by multiple closed osteotomies.

This case should be removed at the end of two weeks and another immediately applied, extending from the toes to the garter line, holding the foot at a right angle and not turned inward or outward. At the end of four more weeks, this cast should be removed and a high, laced shoe, with a three-quarter-inch cork lift for the heel, worn. Weight-bearing with the aid of crutches should be carried out for another two weeks. Contrast baths, baking or diathermy should be employed during this period.

During the course of treatment, emphasis should be placed upon direct sunlight and proper food. If a glandular disturbance is present, proper treatment should be instituted.

If the case is so mild that the foregoing treatment is not necessary, it will be sufficient to elevate the heel, remove the counter of the shoe and insert a pad of felt or sponge rubber in the heel. The heel may be protected by adhesive strapping and the flatfoot corrected. Rubber heels should be worn.

KNOCK KNEE—BOWLEG

These conditions are caused most commonly by rickets and other nutritional disturbances. Deformity should be prevented if possible; if not, it should be corrected. The means of correction include massage, ultraviolet lamp, modifications of the shoes, plaster-of-paris casts, braces and operation.

Indications for Physical Therapy in Various Regions

The various regions will be considered in the following outline: Shoulder, upper arm, elbow, forearm, wrist, hand, hip, thigh, knee, leg, ankle, foot.

Shoulder.—The chief conditions around and in the shoulder joint that are benefited by physical therapy are: (1) arthritis; (2) periarthritis; (3) subdeltoid bursitis; (4) calcification in and around the supraspinatus tendon; (5) brachial birth palsy; (6) fractures and dislocations; the most important being subdeltoid bursitis and calcification of the supraspinatus tendon, arthritis and periarthritis. In arthritis, the tendency is for an adduction deformity with resulting contracture of the subscapularis and pectoralis major tendons. By means of physical therapy these can be prevented and, if they have occurred, much can be done to correct the deformity.

The measures which are most valuable are: rest, radiant heat, massage, passive and active movements, manipulation, plaster casts, braces and diathermy.

Physical therapy agents are of value after fractures and dislocations of the shoulder. One must beware of displacing the fragments in the case of fracture, and displacing bones in the case of dislocation, producing redislocation.

splinting midway between pronation and supination, local applications of heat, very gentle massage and diathermy. Operation is frequently required. After fractures of the elbow in children, there is danger of myositis ossificans. After dislocations about the elbow, physical therapy must be very carefully instituted because of the danger of adhesions and stiffness.

In cases of dislocation of the upper end of the radius with rupture of the orbicular ligament, suture of this structure may be required, using fascia as a plastic means of reconstructing the ligament.

Forearm.—Conditions in the forearm include rupture of muscles or tendons, myositis, fibrositis, paralysis of muscles, pronation contracture, Volkmann's ischemic contracture; posttraumatic, such as fractures and synostosis. The most valuable physical therapy measures are rest, radiant heat, massage, diathermy, and active and passive movements.

Splinting of the forearm, wrist and fingers in cases of Volkmann's paralysis is very important if operation is to be prevented.

Wrist.—The conditions at the wrist which are benefited by physical therapy are: arthritis, fracture, dislocation, fracture and dislocation, epiphysial separation, fracture and dislocation of the carpal bones. The most important fracture is of the scaphoid; the most important dislocation is that of the semilunar. After proper reduction or extirpation of the involved structures, physical therapy measures are of value, and the most important are rest, radiant heat, massage, diathermy, active and passive movements.

Hand.—The important conditions in the hand are contractures of the hand, the fingers and thumb, arthritis, posttraumatic, such as fracture and dislocation, ischemic contracture and wristdrop. The most valuable measures are radiant heat, massage, diathermy, manipulation, active and passive movements, support, such as braces, plaster casts and special splints.

In case of Dupuytren's contracture, many of these can be prevented in the early stages by splints. If they cannot be prevented, operation is indicated. The best operation is that described by Kanavel, Koch and Mason.

Hip.—In the hip the most important conditions are flexion contracture, arthritis, periarthritis and bursitis.

An adduction deformity may require tenotomy of the adductors. In a case of trochanter bursitis—that is, bursitis in the region of the great trochanter—rest, local applications, radiant heat and diathermy are indicated.

Thigh.—In the thigh the important conditions are myositis, fractures, bursitis and paralysis.

thermy, and passive and active movements. Braces, splints and casts are of value. Manipulation under anesthesia is valuable in cases of adhesions.

Bursitis in the elbow region: There is a condition known as tennis elbow, epicondylitis, or radiohumeral bursitis, which is caused by tennis playing and other activities. The treatment includes rest,

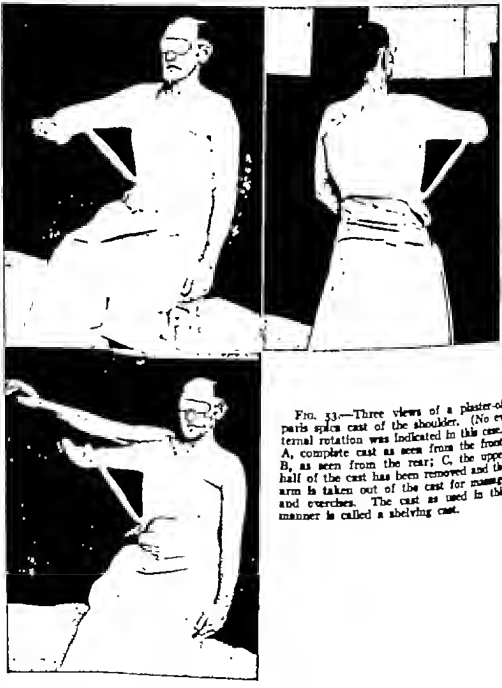


FIG. 53.—Three views of a plaster-of-paris spica cast of the shoulder. (No external rotation was indicated in this case.) A, complete cast as seen from the front; B, as seen from the rear; C, the upper half of the cast has been removed and the arm is taken out of the cast for massage and exercises. The cast as used in this manner is called a shelving cast.

In the thigh, rider's muscle is due to irritation, and in some cases it is amenable to treatment by rest and very gentle massage. In some cases operation is necessary.

Knee.—The important conditions in and about the knee include: arthritis, internal derangements, external derangements, conditions affecting the bones, muscles, tendons, and ligaments, fibrositis, traumatic synovitis, fractures, dislocations and bursitis.

For the knee conditions, one recommends rest, radiant heat, massage and diathermy, which are usually very effective.

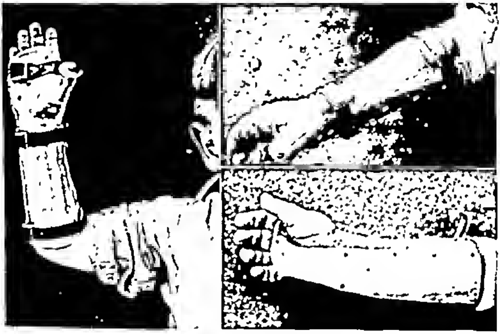


FIG. 57.—Lewin's aluminum forearm and hand splint.

In semilunar cartilage disturbances, the treatment includes manipulation, with or without anesthesia, retention in a plaster-of-paris cast for a few days and physical therapy, including radiant heat and gentle massage. *If the cartilage slips out repeatedly, operation is indicated.*

One of the most important considerations in most knee conditions is: the maintenance of tonicity of the quadriceps muscle by active and passive movements, and electrical stimulation.

The Jones knee cage is a valuable brace in the ambulatory treatment of many conditions.

Leg.—The important leg conditions are fractures, myositis, and circulatory disturbances of the arteries, veins and lymphatics.

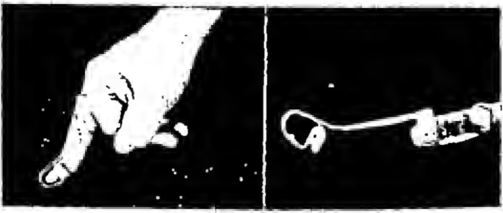


FIG. 54.—Lewin's aluminum splint for baseball finger or dropped phalangette. (Lewin, J.A.M.A., 90, June 30, 1928.)

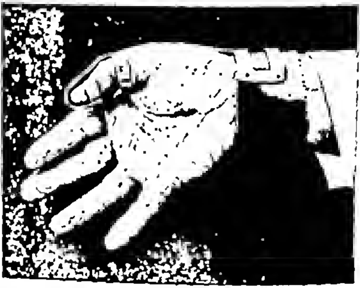


FIG. 55.—Lewin's aluminum splint with leather wristlet to maintain thumb in slight flexion and adduction.

FIG. 56.—Lewin's aluminum splint with leather wristlet to maintain extension of the index finger.

ankylosis. I have divided the treatment into six sections: (1) the proper care of the original causative conditioo whether it be arthritis, sepsis, a gunshot wound or a fracture through or near a joint; (2) the use of physical therapy, especially radiant heat, gentle massage, active and passive movements and diathermy; (3) proper posture, so that if ankylosis supervenes, the joint will be in the best position for future use; (4) the proper use of splints, braces and casts—this includes adjustable splints, bivalved casts and wedged casts; (5) manipulation both by the physical therapist, without anesthesia, after the use of radiant heat and gentle massage under warm water, and by the orthopedic surgeon, under anesthesia. In the case of manipulation, great care, judgment and past experience are oecessary to determine whether *manipulation under anesthesia is indicated* and to *what degree* it may be reasonably carried out; (6) operation which includes synovectomy, osteotomy, cheilectomy and arthroplasty.

The most valuable literature on the subject of stiff joints is that by Sir Robert Jooes, Henderson, Elmslie, Bristow, Bankart and Fisher.

Hysterical stiff joints and malingerer's stiff joint: I saw several cases during my army service in the camps in America, where soldiers, in an attempt to be released from active duty, declared they had a stiff knee in flexion or extension, a stiff elbow, a stiff shoulder or stiff spine. Under anesthesia the stiffness disappeared entirely, and the soldiers were proved to be malingerers.

ARTHRITIS

The writer is not a physical therapist, but, because a large proportion of his work is in the field of arthritis, he has had the opportunity of observiog, critically, the effects of various physical therapy agents and agencies oo individuals suffering from various conditions which, to the majority of clinical observers, have been, correctly or not, included lo the term arthritis.

These conditions are arthritis, synovitis, neuritis, myositis, fibrositis, myofascitis, bursitis, teodonitis, tendovaginitis and gout.

From the orthopedic point of view, in the treatment of a conditioo like arthritis, where so many remedial agents are used, it is difficult to evaluate the effect of each one. The operator, the apparatus and the stage of the disease are variable factors. The patient's statements are of value, although often uncoosciously incorrect.

It is a combination of factors that usually causes arthritis; likewise a combination of ageots may be necessary to relieve or cure it. Physical therapy is an important adjunct in the treatmeot.

The direct treatment of a patient with arthritis deformans may be divided into three divisions, viz., local, focal and general.

The most important factor, especially from the patieot's standpoint, is the relief from paio. This must be accomplished. It should be dooe

In the calf, ruptured Achilles or plantaris tendons are very disabling and painful conditions.

In circulatory disturbances, I wish to call the reader's attention to a point at the crux of the Y made by the gastrocnemius muscle, which is usually a painful spot in certain of these conditions. The treatment includes rest, elevation, special exercises, radiant heat and, in some cases, operation.

Ankle.—The important conditions in the region of the ankle include arthritis, synovitis, fractures, dislocations, sprains, strains and static disturbances.

In cases of sprain of the ankle the treatment includes rest, elevation, the application of cold, adhesive strapping or elastic compression. When walking is permitted, one must prescribe the proper walking-shoe with modifications as needed, crutches and, later on, massage, exercises and contrast sprays.

STIFF JOINTS

In the etiology of stiff joints, the two main divisions are extra-articular and intra-articular factors. There are local and general factors. The tissues to be considered are primarily the cartilage, synovial membrane, tendons and ligaments.

The cause of stiff joints is usually adhesions which may be osseous or nonosseous. Osseous adhesions cause the agglutination of bony surfaces after the articular cartilage has been destroyed. This produces ankylosis. The nonosseous stiffness is due to the formation of adhesive fibrous bands. Hemorrhage is a very important factor.

In the pathology one should consider the primary and secondary factors.

The symptom of stiff joints is immobility. Pain may or may not be prominent. It may be the all-important factor in preventing movement during the period when the joint is becoming stiff. After ankylosis has occurred, there is usually no pain unless the ankylosis is disturbed by force. Roentgenograms may be very deceptive in determining whether complete ankylosis is present or not. I have seen roentgenograms which indicated complete ankylosis and was surprised to find considerable movement in the joint. I have seen other roentgenograms where no indication of ankylosis was present, but the joint was stiff due to fibrous adhesions and pain.

The prognosis in the case of a joint that is becoming stiff, or in one that is already stiff, should be guarded. One is given surprises in both directions.

Treatment.—The treatment of stiff joints concerns preventive, prophylactic, curative factors and means to prevent a relapse or re-

FIG. 59.—Roentgenogram of the lumbar spine illustrating hypertrophic arthritis. Note the bony bridging across several vertebrae.

while a thorough search for the etiologic factors is being made. The joint should be put at rest. The patient is put to bed, not allowed to get up for meals or to go to the lavatory. The painful part is swathed with strips of gauze saturated with an anodyne lotion.

During the acute stage of all forms of arthritis, when soreness, congestion and pain of the joints are present, the first great fundamental principle of orthopedic surgery should dominate the treatment. Deformity must be prevented. Proper positions, protection splints and rest accomplish this. Joints at this time should never be manipulated or strained, because the resulting swelling mechanically interferes with circulation, and trauma is done to diseased tissue. Painless active

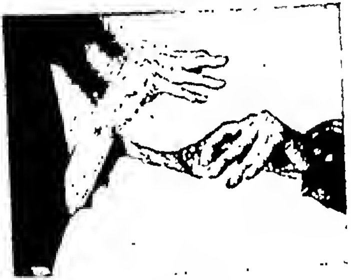


FIG. 58.—Atrophic arthritis of the hands with deformities.

motion is encouraged. After the acute stage has passed, however, the joint function must be restored if possible. The best results have been secured through very gradual use of the joints by exercises and occupational work. Manipulation is used less and less, and the quicker method is being displaced by more gradual and, on the whole, more satisfactory daily exercise, with rest periods. By this, the muscles are developed to keep pace with the increased range of motion, and better circulation follows with more permanent results. If later, operative procedures are necessary to obtain joint motion, the muscles, having been used, are ready to do their share in securing motion much sooner after operation, and the danger from adhesions becomes less because of this preparation.

In arthritic conditions one must realize the importance of coöperation between the orthopedic surgeon and the internist.

FIG. 61.—Lewin's method for strapping the pelvis for low back pain.

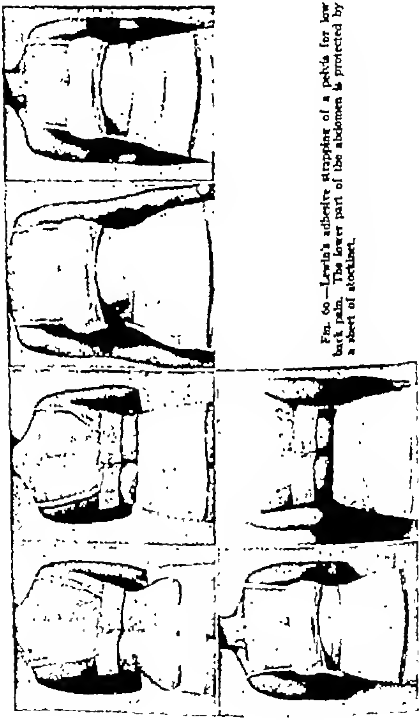


Fig. 60.—Lewin's adhesive strapping of a pelvis for low back pain. The lower part of the abdomen is protected by a sheet of stockinet.

In the treatment of arthritis of the spine, one should consider traction, Bradford frame, heat, massage, diathermy, posture, exercises, strapping, braces, belts and electrical stimulation of atrophic muscles.

SCIATICA—SCIATIC SYNDROME

Sciatica, or the sciatic syndrome, is a condition characterized by pain along the course of one or more of the nerves of the lumbosacral plexus; the most common radiation of pain is down the back of the thigh, into the leg and down to the heel. The pain, however, may

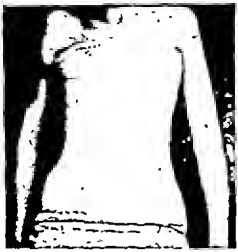


FIG. 64.—Plaster-of-paris body cast used in the treatment of arthritis of the upper lumbar spine.

radiate down the inner or outer border of the thigh, rarely down the front. The term *sciatic syndrome* is preferable to sciatica or sciatic neuritis. It is not a neuritis, but a neuralgia or symptomatic neuritis. Primary sciatic neuritis is a rare condition usually caused by lead, arsenic, syphilis or alcoholism. The symptoms include pain, with limitation of movement and, in cases of sciatic scoliosis, a lateral shift of the body. Roentgenograms often reveal hypertrophic arthritis in the lumbosacral or sacro-iliac joints, or both. The differential diagnosis is important, and one must exclude cord tumor and tuberculosis and malignancy of the spine. In order to exclude cord tumor, every patient should have a neurologic examination.

The treatment includes removal of foci of infection, such as in the teeth, tonsils or intestinal tract. Treatment of the arthritis of the spine includes symptomatic treatment to relieve pain. Radiant heat, gentle massage and diathermy are usually effective. In some cases massage

ARTHRITIS OF THE SPINE

Arthritis of the spine is usually of the hypertrophic type. Pure, uncomplicated atrophic arthritis of the spine is rare. In fact, there are numerous clinicians who are unable to recall one instance of uncomplicated atrophic arthritis of the spine, even though they have seen large numbers of the hypertrophic type. Therefore, we may say that arthritis of the spine is usually of the hypertrophic type manifested by pain, local and referred, limitation of motion, a stiff or even a poker spine, tenderness to movements, sensitiveness to jarring, pain on sneezing, coughing or straining at the stool; roentgenograms revealing the hypertrophic or osteo-arthritic changes.

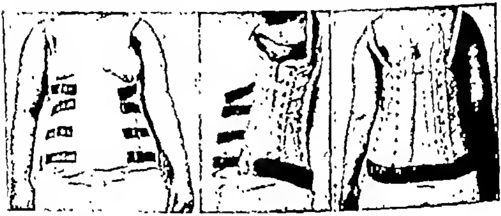


FIG. 62.—Corset spine brace.

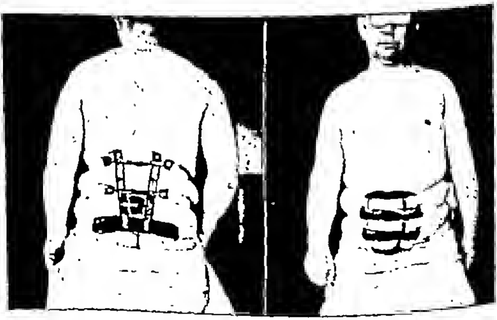


FIG. 63.—Low back brace.

and diathermy may aggravate symptoms. Putti recommends a bivalved cast made with the patient in the deformed position, and the use of heat from an alcohol lamp in the form of Bier's hyperemia. In some cases it is advisable to stretch the lumbar spine and limb, described under "manipulation of the spine." I have had considerable success with the combination of caudal epidural injection of 1 per cent novocaine combined with manipulation under anesthesia.

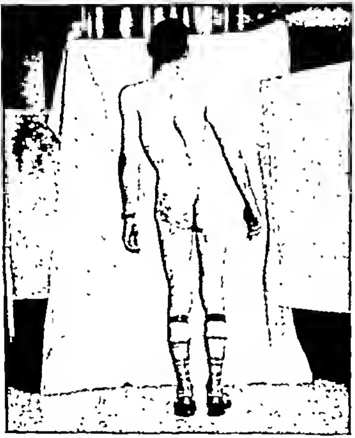


FIG. 66.—Sciatic scoliosis due to arthritis at the lumbosacral joint.

BRACHIAL NEURITIS

Brachial neuritis corresponds with the sciatic syndrome. Brachial neuritis means pain along the course of one or more of the nerves of the brachial plexus. The cause is usually hypertrophic arthritis of the cervical spine. The symptoms include pain along the distribution of the nerves of the brachial plexus. Roentgenograms may show hypertrophic arthritis of the cervical spine. The treatment includes treatment of the primary conditions or foci of infection, symptomatic treatment for pain, rest, support, heat, massage, diathermy and very gentle manipulation.

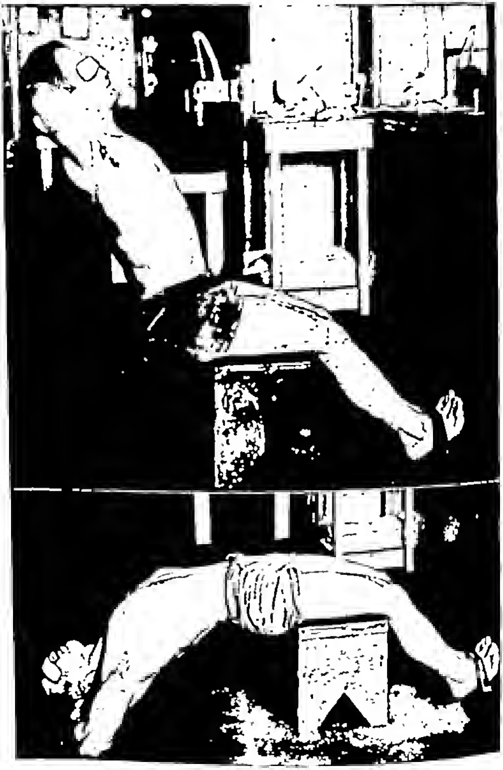


FIG. 65.—Two views of the stall-bar exercise to obtain hyperextension of the spine. This is a severe exercise. It must not be prescribed where any acuteness of symptoms is present. (Lewin, J.A.M.A., 88, April 23, 1927.)

The treatment of the congenital type may be divided into early, intermediate and late treatment. The measures which are of value include exercises, massage, and correct posture day and night. Immobilization can be secured by means of a special collar made of cotton, a brace or a cast. Operation includes division of the sternal and clavicular heads of the sternocleidomastoid muscle, or a plastic operation known by the name of Foederl. After operation, a cast to maintain overcorrection is advisable, this to be followed by a brace, exercises and massage.

Included in TRAUMATIC TORTICOLLIS should be mentioned ordinary stiff neck due to exposure to changes in temperature. An ordinary stiff neck that a patient awakens with is usually due to a myositis or a neuritis. This torticollis occurs during sleep, when a draft of cool air blows on the neck causing congealing of the muscles and compression of the nerves, or a neuralgia followed by muscle contracture or fibrositis. The treatment includes radiant heat, gentle massage, gentle manipulation and the application of a cotton collar.

In OCULAR TORTICOLLIS, the treatment includes, in addition to the orthopedic management, the correction of the ocular disturbance.

In HYSTERICAL TORTICOLLIS, the physical therapist and the orthopedic surgeon can be of great assistance to the psychiatrist.

NEUROLOGIC CONDITIONS

The chief neurologic conditions to be discussed include poliomyelitis, spastic paralysis, brachial birth palsy, syringomyelia, tabes dorsalis, multiple sclerosis, hysteria, pseudohypertrophic muscular paralysis, ataxia, peripheral nerve wounds and other paralytic and neuromuscular conditions.

In the treatment of tabes, the physical therapist can do a great deal in neuromuscular reëducation by the various methods, such as the Frenkel series. In maintaining the tone of the skin, muscles, ligaments and nerves, massage very carefully applied is valuable. Exercises under warm water are beneficial. As aids in locomotion, crutches, canes and various mechanical walkers are useful.

In the treatment of multiple sclerosis, one should try radiant heat, very gentle massage, exercises, neuromuscular reëducation and underwater exercises. Sometimes diathermy is beneficial. The use of canes, crutches and other walking apparatus is helpful.

The same physical therapeutic measures are applicable to tabes dorsalis or locomotor ataxia and syringomyelia. As is well known, Charcot joint is usually found in the lower extremity, syringomyelic joints in the upper extremity. The physical therapy measures include rest, radiant heat, gentle massage, neuromuscular reëducation, underwater gymnastics and the various aids to locomotion, such as walking apparatus, canes and crutches.

FIG. 67.—A cotton collar used in the treatment of brachial neuritis. It exerts traction and distraction, affords support and immobilization, retains heat and prevents exposure to drafts.

FIG. 68.—Torticollis, or wryneck. Chin is pointing toward the left. Distance from right ear to shoulder shorter than on opposite side.

TORTICOLLIS

Torticollis, or wryneck, may be congenital or acquired. The acquired type is usually due to trauma, ocular disbalance, and psychic disturbances such as hysteria.

The treatment of the congenital type may be divided into early, intermediate and late treatment. The measures which are of value include exercises, massage, and correct posture day and night. Immobilization can be secured by means of a special collar made of cotton, a brace or a cast. Operation includes division of the sternal and clavicular heads of the sternocleidomastoid muscle, or a plastic operation known by the name of Foederl. After operation, a cast to maintain overcorrection is advisable, this to be followed by a brace, exercises and massage.

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The Smart-Bristow coil is of value in correcting the atrophy both of disuse and of neurotrophic origin.

In the treatment of *hysteria*, physical therapeutic measures are of great value, especially the various hydrotherapeutic measures, including warm baths, short cold spray, contrast sprays, alternating heat and cold, gentle massage, ultraviolet rays, neuromuscular training and underwater exercises. Sometimes it is advisable to apply a plaster cast to a hysterical foot in order to allow the patient to bear normal weight upon it. In some extreme cases it is justifiable to do a minor operation, such as lengthening of an Achilles tendon, in order to correct a hysterical contracture.

Metabolic Conditions

The chief metabolic conditions include arthritis, gout, rickets and obesity. In *arthritis*, the most valuable physical therapeutic measures include rest, heat, massage, diathermy, negative galvanism and local applications.

In a discussion of *gout*, one should emphasize the importance of diet, exercise and physical therapy, including ionization.

The subject of *obesity* is a very important one. As a general proposition, obesity is due to overindulgence in food, lack of exercise and constipation. There are other factors such as hereditary tendency and disturbances in the endocrine glands, and of water metabolism. The important physical therapy measures include massage, exercises in the open air, including walking, tennis, golf, bicycle riding, rowing and other sports. Jumping the rope, tap-dancing and setting-up exercises are very valuable. Other measures include colonic irrigation, implantation of acidophilus organisms, laxatives, cathartics and the elimination of certain foods.

So far as the question of diet is concerned in the treatment of obesity, it is a general proposition that the patient's weight is the difference between his intake and his output. There has been considerable discussion on the subject of endogenous and exogenous obesity, but when all the evidence is weighed, it comes down to the simple proposition that the patient's weight is the difference between the amount of food taken in, the type of food, the metabolism of the food and the energy output, such as in exercising, and his excretions.

There is, undoubtedly, a definite type of constitution of the individual—an inherited constitution. Endocrine factors are undoubtedly important, but the exact nature has not yet been determined. Failure to recognize the factor of obesity and to institute proper procedure has been the cause of many failures in the treatment of conditions involving the extremities and the lower back. These conditions are chiefly arthritic, metabolic and mechanical, including flat feet and painful heels.

The reader is referred to such works as McLester, Evans and Strang, and Newburgh. Fads and fancies in diet are largely due to misinformation fostered by the cultists or as a result of prejudice of unthinking people.

Obesity is a very important consideration in orthopedic cases, especially from the mechanical standpoint, in the following conditions: anterior poliomyelitis, flat feet, painful heels, sacro-iliac disturbances,

FIG. 69.—Extreme deformities occurring in twins who had rickets.

arthritis of all the joints, especially those of the spine, hip, knee and ankle. The overweight child is the precursor of the overweight adult.

Fashion in recent years has decreed, according to Barborka, that the figure of women should be sylph-like; to conform to this, many women have employed, on their own initiative, many ridiculous dietary measures. Not infrequently, this has led to extreme under-nutrition, to ill health and even death. It is the physician's duty to point out the limits of reduction, and that health is more to be desired than a fashionable figure.

After an injury to the foot or ankle or knee, such as occurs in industrial conditions, especially fractures and dislocations of the lower

extremity, obesity may be a very important stumbling-block which favors prolonged disability.

Endocrine Disturbances

Under endocrine disturbances, the physical therapist is especially concerned with such conditions as obesity, leanness, Fröhlich's syndrome and slipped epiphysis.

The chief glands of internal secretion which are on a fair basis of scientific therapeusis include the thyroid, parathyroid, pituitary, adrenal and ovary.

Physical therapy measures include support, casts, splints, massage and diathermy. Endocrine therapy and sometimes operations are indicated.

Circulatory Conditions

The most important circulatory conditions include varicose veins, endarteritis obliterans, thrombo-angiitis obliterans, Raynaud's disease and causalgia. Thrombo-angiitis is known as Buerger's disease. Space does not permit description of the various tests for the efficiency of the circulatory apparatus.

The best treatment for varicose veins is the injection of sclerosing solutions. This is a minor procedure in the hands of a qualified surgeon.

It has been stated that 95 per cent of Buerger's disease cases occur in men and 5 per cent in women, which is just the opposite of the figures for Raynaud's disease.

The importance in the treatment of circulatory disturbances is to improve circulation. The means of accomplishing this include rest, elevation of the limb, heat, elastic compression, diathermy locally and to the cervical and lumbar sympathetics, special circulatory and postural exercises. Operations on the veins, arteries and sympathetic nerves are not discussed here.

The most valuable postural circulatory exercises are those described by Buerger * under the conservative treatment of thrombo-angiitis obliterans. He says: "When the disease is well developed, distinct intermittent claudication being present and fairly marked pain with or without trophic disorders, it is advisable that the patient remain in bed for several weeks or even longer, or at least that walking and standing be completely interdicted. Therapeutic measures should be directed toward the conservation of warmth, enhancement of the circulation, the prevention of traumatism, and the treatment of local conditions, trophic disorders or gangrene when these supervene."

The author has suggested that certain passive exercises may be of value in inducing hyperemia or rubor in the affected limb and, therefore, therapeutically beneficial in increasing the blood supply.

* Buerger, Leo: Circulatory Disturbances of the Extremities, Ed. 1, Phila., W. B. Saunders Co., 1924.

This method is the logical therapeutic outcome of Buerger's method of diagnosticating impairment of circulation of the lower extremities, in that it uses the phenomenon of induced rubor or induced hyperemia in a therapeutic way. If the method be carried out daily for a sufficiently long period, it is of greater value in improving the circulatory conditions and in increasing the blood supply than any of the other mechanical or thermal means that are at our disposal.

The procednre is as follows: "With the patient lying supine, the affected limb is elevated to from 60 to 90 degrees above the horizontal, being allowed to rest upon a support for from 30 seconds to 3 minutes, the period of time heing the minimum amount of time necessary to produce hlanching or ischemia. As soon as blanching is established, the patient allows the foot to hang down over the edge of the bed for from 2 to 5 minutes, until reactionary hyperemia or rubor sets in, the total period of time being about 1 minute longer than that necessary to estahlish a good red color. The limb is then placed in the horizontal position for about 3 to 5 minutes, during which time an electric heating pad or a hot water bag is applied, care being taken to prevent the occurrence of a burn. The placing of the limb in these three successive positions constitutes a cycle, the duration of which is usually from 6 to 10 minutes. These cycles are repeated over a period of about one hour, some 6 to 7 cycles constituting a séance.

"The number of séances cannot be categorically stated but should vary with the case. In a general way they should occupy at least 6 to 7 hours a day, that is, every alternate hour during the daytime. During the hours of rest, heat is applied continuously in the form of an electric pad, hot water bag, hot air apparatus or electric lamp. In the opinion of the author, this method does far more to improve the circulation than either the application of superheated air (so-called baking treatment) or the diathermic treatment.

"The length of time of its application may require modification, according to the manner in which the procedure is borne. In some cases, pain induced by elevation may necessitate a diminution in the period of elevation.

"It is not possible to lay down hard and fast rules as to the exact application of this method in any given case. Its employment should be varied according to the requirement of each and every clinical stage and the patient's response."[1]

In the treatment of arteriosclerosis, Buerger recommends several methods of improving the circulation.

These include, first, the postural treatment; second, the hot air treatment; third, the diathermic treatment; fourth, the heat of electric lamps; fifth, the thermophore.

The postural treatment, which consists in the indnction of a reactionary hyperemia in the affected part by preliminary elevation of the leg, followed by depression of the limb in a dependent position,

may be used with some benefit in almost all cases, except where gangrene has already become extensive, where a phlegmon has developed or where such changes of position are too painful to the patient. When recent extensive thrombosis has taken place, it is also contraindicated.

The postural treatment, or exercises to induce rubor and an accelerated circulation, must be varied in its method of application in each and every case. "The period of elevation should be the minimum amount of time necessary to produce a frank blanching of the foot. This is usually about 30 seconds to 3 minutes, depending upon the degree and extent of the vascular obstruction. The next period of depression (or of the hanging leg) is to be prolonged about 1 or 2 minutes beyond the time necessary for the induction of distinct rubor. An abridgment of this is then warranted, when the patient complains of increased pain in this position, or if the pain becomes unbearable after a given duration of time. The third position of rest in the horizontal may be extended at will beyond 3 minutes, provided that this does not suffice to give enough repose to the patient. In general, it should be longer in the atherosclerotic cases than in the younger people affected with thrombo-angiitis, since the former may find the treatment onerous unless sufficient intervals of rest are provided.

"The position of the resting limb in all forms of obstructive arterial disease has not received attention from the clinicians. If careful observations on the appearance of such limbs in varying postures be made, especially after the induction and abatement of reactive circulatory manifestations, it will be noted that the color of the foot varies considerably when in the horizontal plane. While a normal or slightly diminished flesh color is not infrequently seen even in advanced arterial disease, the affected foot will often evidence varying degrees of pallor. This may affect but one or more toes or the fore part of the foot, or it may involve even some of the distal portions of the leg; the dorsum or plantar aspect of the foot may show patches of blanching alternating with pinkish or slightly cyanotic areas. All of these color manifestations must be interpreted as indicating a circulatory insufficiency in this position, and, as such, we may deduce lessons of prophylactic and therapeutic value—to wit, that such limbs are not to be allowed to stay during their period of rest, in the horizontal position, but somewhat depressed, just enough to bring about color evidences of circulatory activity. After testing the angle necessary to bring about the return of almost normal color, the patient must be instructed that this particular position is to serve as his horizontal. Indeed it is well, even when asleep, to arrange the bed so as to conserve the angle previously arrived at, for, harmful as is the continued stasis induced by prolonged standing or walking, so also is one of continued ischemia, even if but slight. A position of elevation universally regarded as harmless must be avoided because of its depleting effect."

Pseudohypertrophic Muscular Paralysis

This condition is variously known as pseudohypertrophic muscular paralysis and progressive muscular dystrophy.

The cause of the condition is unknown. The signs and symptoms include the following: There is a history of delayed walking, sometimes until the third or fourth year. Tiptoe walking is the rule. The gait is awkward, waddling and unsteady with inability to go up and down stairs. Children fall frequently and are usually unable to arise without assistance. They tire easily. There is a marked lordosis and a protuberant abdomen. Usually the calf muscles are enlarged and very firm. There is a peculiar facial expression which is dull and mask-like with inability to elevate the angles of the month so that when the child smiles, the lips spread out sidewise but the angles of the mouth are not elevated. In walking, the feet are wide apart, and sooner or later they assume a position of equinus or toe drop. They are swung forward rather than lifted and carried high to clear the ground. The child sways from side to side and he cannot sit down slowly—he collapses into a chair, unless he uses his arms and hands to break the fall. Winged scapulae are due to muscular atrophy. There are noted a wasp-waist and loose shoulders. Stumbling and falling are prominent features. If the child can rise from the lying position on the floor, he usually does so in a classic way. He turns over on his face; he rests on his elbows and knees, climbs up on his legs by putting his hands on his ankles, then the legs, then the knees and then the thighs and, finally by a supreme effort, stands up.

The treatment of this condition includes no specific remedy. For many years I have used hypodermic tablets of adrenalin, 3/200 of a grain each, dissolved under the tongue three times a day. More recently, Kure and Okinaka advocate the use of adrenalin and pilocarpine subcutaneously. The dose for adrenalin is 0.2 to 0.3 cc. of a 0.1 per cent solution. The dose for pilocarpine is 0.1 to 0.2 cc. of a 1 per cent solution. The injections are repeated daily or every second day until at least 50 injections are given.

The physical therapeutic measures are as follows: The first warning is to avoid fatigue. Electricity is of value in maintaining good tone and circulation. Massage is of some value. Hydrotherapy is valuable. In order to teach these patients to go up and down stairs, it is advisable to use a set of 5 or 6 narrow stairs, with a balustrade on each side. Retention apparatus, as a rule, is not highly beneficial. As a means of preventing contractures and deformities, it is advisable. A light removable plaster cast or brace may be used to hold the foot at a right angle, or a knee in extension, or to support a scoliotic back.

Tendon lengthening and tenotomies, when indicated, should be performed very carefully because of the danger of losing what little

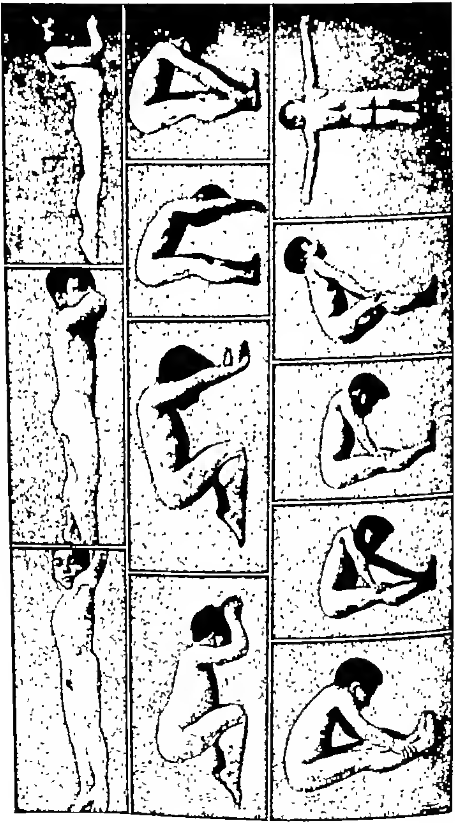

Fig. 70.—Twelve views of a child with pseudohypertrophic muscular dystrophy arising from the ground in the typical manner of "climbing up his legs." (Lewin, J.A.M.A., 87, August 7, 1926.)

tone or power their muscles have. and because of the danger of producing the opposite deformity which may be more disabling.

Shoes and Their Modifications

In a discussion of shoe modification, first of all one must consider the type of shoe that is advisable for children, women and men. As a general proposition, one may say that a shoe should be straight lasted, round toed, have a moderate height of heel and a rigid shank.

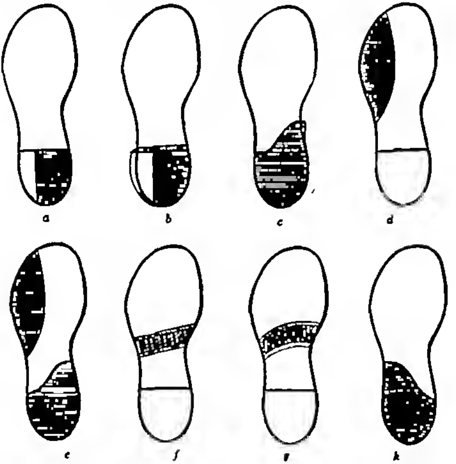

Fig. 71.—The most commonly prescribed modification of shoes (The left shoe is shown.)
a. Elevation of inner border of heel
b. Elevation of inner border of a flared heel.
c. H. O Thomas heel—prolongation forward and elevation of inner border.
d. Elevation of outer border of sole
e. Combined Thomas heel plus elevation of outer border of sole.
f. Metatarsal cleat
g. Metatarsal crescent
h. Reversed Thomas heel Outer border prolonged forward and elevated.
The sketches were made by Dr. D. H. Levinthal.
The modifications most commonly used are the special heel of H. O. Thomas, modification of the sole, and the metatarsal crescent or cleat. [Philip Lewin, J. Bone & Joint Surg., 12 665-669 (July) 1930.]

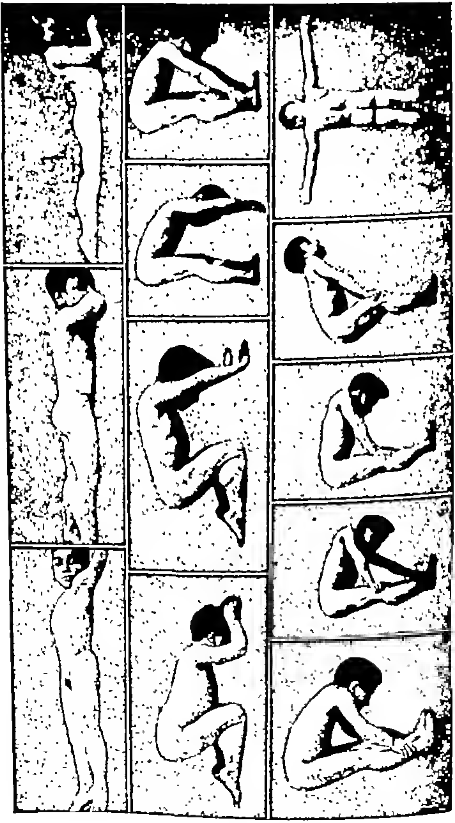

Fig. 70.—Twelve views of a child with pseudohypertrophic muscular dystrophy arising from the ground in the typical manner of "climbing up his legs." (Lewin, J.A.M.A., 87, August 7, 1926.)

muscle pull or muscle imbalance produces disturbances of posture, but to a certain extent these inherited tendencies can be overcome. Bad posture in many instances is only a result of habit and, by the exertion of will power and by proper exercises, good posture habits can be acquired. Deformity and disease have an influence on posture;

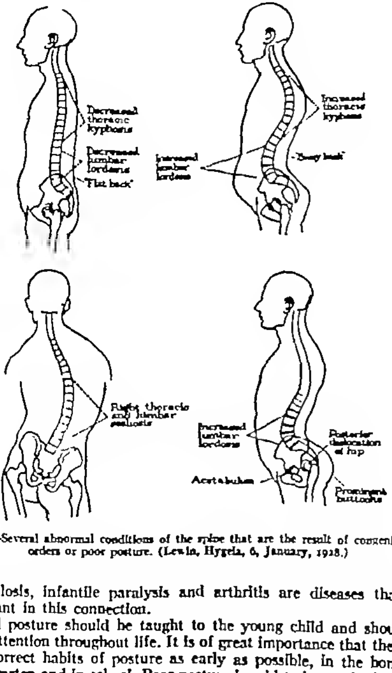

Fig. 72.—Several abnormal conditions of the spine that are the result of congenital disorders or poor posture. (Lewin, Hygeia, 6, January, 1928.)

tuberculosis, infantile paralysis and arthritis are diseases that are important in this connection.

Good posture should be taught to the young child and should be given attention throughout life. It is of great importance that the child form correct habits of posture as early as possible, in the home, in kindergarten and in school. Poor posture is said to be on the increase, and there is no doubt that it adds greatly to the stress and strain of

It must be narrow in the heel and through the waist of the foot, but wide through the ball.

There is comparatively little difficulty in obtaining properly shaped shoes for children and men, but for girls and women the matter is entirely different. Women are the victims of two things: one is style and the other is the shoe salesman. Women prefer to fit the eye rather than the foot, and please the eye rather than their husband's good sense.

The chief modifications in shoes include modifications of the heels, soles, counters and the big-toe region. The chief modification of the heel is the Thomas heel, which is longer and higher on the inner border than the outer border. This compels the individual to walk over the proper walking-angle, so that a weight-bearing line dropped from the middle of the patella bisects the tibia and the astragalus.

The chief modification of the sole is the elevation of the outer border where the highest point of the wedge should be under the base of the fifth toe.

Modifications of the counters include the removal of the counter for irritation of the heel, and the prolongation of the counter on the inner border to protect and support the scaphoid, first cuneiform and base of the first metatarsal.

Modifications in the region of the big-toe joint include making the sole rigid, so there will be no motion in the big-toe joint, which may be beneficial in relieving the pain in cases of osteo-arthritis of the big-toe joint.

The chief modification of the sole is what is known as a metatarsal bar or cleat, which consists of a strip of leather secured between the layers of the sole at a point just behind the heads of the metatarsal bones.

Posture *

There is health as well as beauty in correct carriage, and many serious disorders of the human body are due in whole or in part to poor posture.

An imaginary plumb line dropped from the side of the head should pass through the ear and through the middle of the shoulder, hip, knee and ankle bone, if a person has a correct standing posture. By performing the following movements, one will attain excellent form: (1) stand with the back against the wall; (2) let the head and buttocks touch the wall but place the heels forward four inches; (3) flatten the lumbar region, attempting to touch the wall with the lumbar spine; and (4) holding the body erect shift the weight forward to the balls of the feet and step off, maintaining the body in this position.

A person inherits from his parents and ancestors a certain type of back and a certain type of posture just as he inherits many other characteristics. Muscular weakness also is inherited, and unequal

* Lewis, Philip. Hygeia, 6:3 (Jan.) 1928.

and mouth to function better. The person with erect carriage actually thinks better; he is more level-headed.

In the chest also, poor posture causes disturbances. The cramping results in improper physiologic action of the heart and lungs. The diaphragm, the large muscle that separates the thoracic from the abdominal cavity, cannot do its work properly when posture is unnatural.

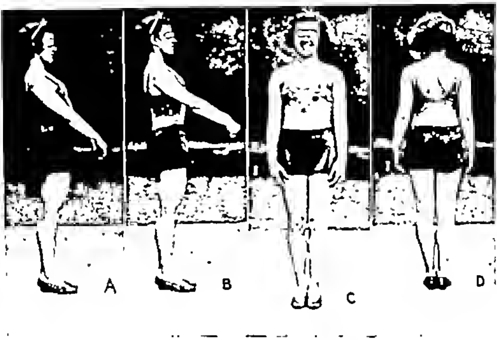

FIG. 74—A, poor posture due to exaggerated lumbar lordosis; B, C and D, correct posture.

Proper support is not provided the abdominal organs—stomach, liver, gallbladder, pancreas, small intestine, large intestine and omentum—when posture is bad; they are cramped and forced out of their normal positions. With the stomach at a lower level, intestines pushed down, kidneys improperly supported and strain on the various suspensory ligaments, it is simple to deduce what symptoms follow. The circulation of these tissues is impeded, and constipation, an important factor in the production or aggravation of many chronic conditions, results.

The pelvic organs in persons of both sexes may suffer materially. In women the effects of poor posture often reflect themselves in the uterus, ovaries and fallopian tubes.

Poor posture of the lower extremities results in mechanical and other disturbances, chief of which are strain on the hip joint and mechanical strain on the knee joint, ankle and foot. Undoubtedly many

both child and adult life; it also exposes the individual to the possibility of superinduced infection and trauma.

The spine is a flexible rod made up of segments, at one end of which sits the head and at the other end of which sits the person. The spine has a normal front to back (anteroposterior) curve; it curves forward, backward, forward and backward again as one progresses from the neck to its base; but in the lateral, or side to side, plane there are no normal curves. Any lateral deviation involving more than

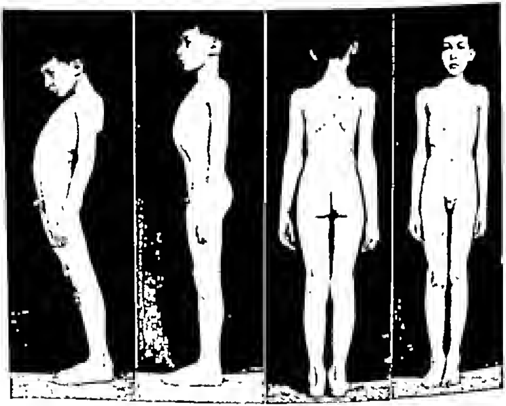

FIG 73.—After three weeks of medical gymnastics, this boy's posture improved from the condition shown on the left to the erect carriage illustrated on the right. [Philip Lewin, Hygeia, 6:3 (Jan.) 1928.]

one vertebra is called scoliosis. As it is a flexible rod, one portion of the spine cannot be changed without a compensatory change in at least one other portion.

Man was not intended to walk upright. Many human disorders are penalties for his having assumed the upright position. Without good posture the brain, heart, lungs, liver, kidneys, pancreas, muscles and ligaments are hindered in proper function, and elimination from the gastro-intestinal tract is retarded.

Erect carriage of the head and proper curving of the neck permit the muscles, ligaments, bones, joints, blood vessels, brain, eyes, ears, nose

and mouth to function better. The person with erect carriage actually thinks better; he is more level-headed.

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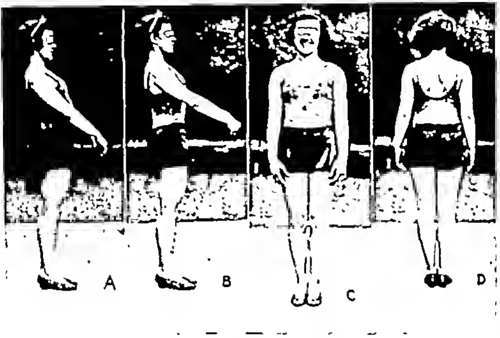

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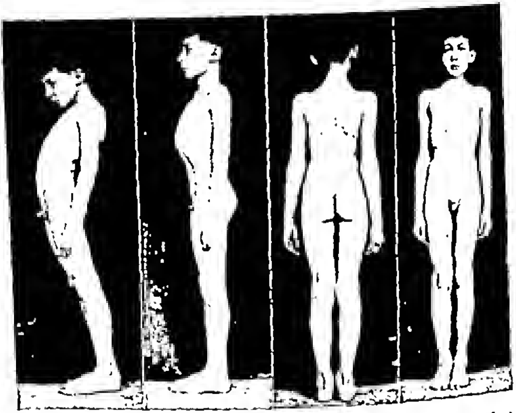

FIG 73.—After three weeks of medical gymnastics, this boy's posture improved from the condition shown on the left to the erect carriage illustrated on the right. [Philip Lewin, Hygeia, 6:5 (Jan.) 1928.]

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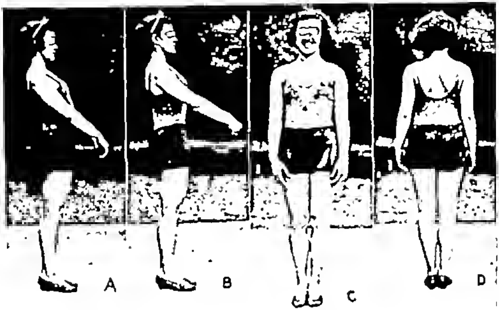

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The pelvic organs in persons of both sexes may suffer materially. In women the effects of poor posture often reflect themselves in the uterus, ovaries and fallopian tubes.

Poor posture of the lower extremities results in mechanical and other disturbances, chief of which are strain on the hip joint and mechanical strain on the knee joint, ankle and foot. Undoubtedly many

cases of arthritis of the knee and hip are traceable to basic mechanical disturbances that have been in operation over a period of many years.

Flatfoot is a result of poor posture in many cases and may be a disabling condition. The combination of a mechanical disturbance, such as pronation of the foot, with strain, overactivity, injury or infection, is a common cause of foot disability.

The methods of recording posture are the photograph; the schematograph, which was invented by Dr. Mosher and Prof. Lesley of Leland Stanford University and is a camera-like instrument with a focusing lens and a series of mirrors, by which an image is thrown on a sheet of clear glass on which is superimposed a piece of tracing paper; and the silhouetteograph, devised by Norman Fradd, which makes a graphic record of the posture by an arrangement for photographing the individual in silhouette.

Roentgenograms are of value in determining the position and shape of the bones. They often reveal definite unsuspected disease conditions.

Treatment.—The treatment of postural defects consists of prophylactic and remedial measures. Prophylactic measures consist of such considerations as balancing the pelvis in cases of inequality of the length of legs. Attention to the feet is important. The remedial agents are rest, medical gymnastics and support. The mattress must be made rigid by the insertion under it of boards or a wooden frame. The Bradford or Whitman gas-pipe frames are valuable in some cases. Stretching, consisting of head traction, leg traction, pelvic traction, or combinations of two of these three, is valuable as preliminary treatment.

Medical gymnastics consist of postural, corrective, flexibility, power-increasing, breathing and relaxation exercises. In postural exercises, the patient is taught to stand tall, sit tall, lie tall and think tall. He learns to walk with his chest thrown forward, his abdomen drawn in, his lumbar curve flattened, his shoulders well back and upward and his head upward so that he looks out of the centers of his eyes; the chin is drawn straight back. He walks "chesty."

Corrective, flexibility and power-increasing exercises are self-explanatory. Breathing exercises, such as those emphasized by Goldthwait and Klein, are valuable. Relaxation exercises have a definite place in this treatment. The so-called stall-bar exercise is of considerable value in low back conditions. Swimming and ballet dancing are excellent.

When supports are necessary, a simple corset is to be considered. The orthopedic surgeon in some cases may prescribe the wearing of a corset reënforced either by a steel frame or by an aluminum cage. Braces, celluloid jackets, aluminum jackets and plaster-of-paris casts are sometimes necessary in severe cases. Plaster casts may be removable.

Physical therapy, consisting chiefly of massage, is of great value. Hydrotherapy, heliotherapy, phototherapy and tonics have their places in the treatment.

I have designated the following ten commandments of good posture:

1. Stand tall.
2. Sit tall.
3. Walk tall and "chesty" with weight transmitted to balls of feet.
4. Draw in abdomen, pulling it backward and upward.
5. Keep shoulders high and square.
6. Pull chin straight backward toward collar button.
7. Flatten hollow of back by rolling pelvis downward and backward.
8. Separate shoulders from hips as far as possible.
9. Lie tall and flat.
10. Think tall.

Conclusion

In concluding this chapter, I wish to emphasize the importance of physical therapeutic agents in the prevention and correction of deformities and disabilities of the extremities. In every community there should be at least one institution where physical therapy can be given in an ethical manner, under the control and guidance of a licensed practitioner of medicine.

The author wishes to express his thanks to Lea & Febiger for the use of a considerable portion of this manuscript and many of the illustrations to be used in his forthcoming book, *The Principles and Practice of Orthopaedic Surgery;* also, to W. B. Saunders Company for the use of some of the manuscript and some of the illustrations from his book, *Orthopaedic Surgery for Nurses.*

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CHAPTER TWELVE

PHYSICAL THERAPY IN PLASTIC SURGERY

Vilray P. Blair, M.D., and James Barrett Brown, M.D.

Physical and Occupational Therapy in General

The application of physical and occupational therapy plays an indispensable rôle in the care of many patients who have to undergo extensive plastic repairs of defects.

Plastic operations may include the repair of recent lacerations. Again, a rather long series of plastic operations may be necessary to overcome serious defects in facial appearance and function, such as deforming scars from burns, or scars following operations for carcinoma. Finally, the plastic operation may be performed to restore function to a part, as in a temporomaxillary ankylosis, or to replace deforming scars with contractures about the trunk or extremities. In all these conditions physical therapy must play its part if the ultimate aim of the operative procedure is to be attained.

Severe scarring and contracture deformity about the hand and fingers may be taken as a given case. After a long period the part may still be swollen and congested or it may show atrophy and poor blood supply. Heat, hydrotherapy, and massage for one to four weeks prior to the proposed reconstructive operation will usually improve the blood supply, overcome a certain amount of the contracture deformity, limit the degree of atrophy from disuse, and altogether so improve the condition of the part as to assure the best possible operative result. Following operation on the hand, physical therapy in the nature of proper splinting is immediately introduced. A little later, hydrotherapy is employed, and as soon as the healing of the wounds permits, massage and muscle-training exercises are added to the treatment. Long after the surgical wounds have healed, the daily use of massage, muscle-training exercises, active exercises, and finally, work or play, are necessary and should be persisted in until the greatest possible functional restoration is secured (Figs. 1-8).

Physical Therapy Agencies in Plastic Surgery

In plastic surgery the following physical therapy agencies are most commonly used:

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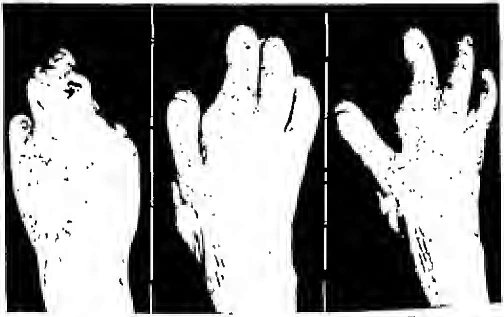

FIG. 1 FIG. 2 FIG. 3

FIG. 1.—The hand has been left a scarred mass, following a severe burn.

FIGS. 2 and 3.—Reconstruction of hand by removing scar to establish joint movement and covering the dorsum with a pocket flap from the abdomen. The space between the fingers was restored with free grafts after the abdominal flap was in place.

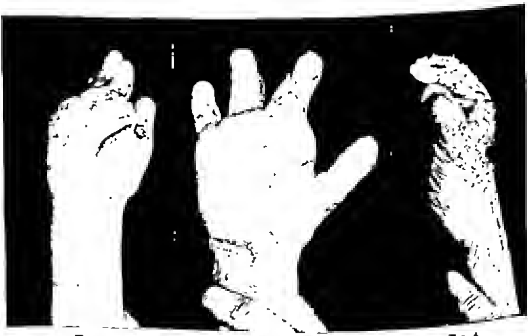

FIG. 4 FIG. 5 FIG. 6

FIGS. 4, 5, and 6.—Different views of same hand.

FIG. 7.—Patient at work in occupational therapy shop after restoration of hand shown in Figs. 1-6.

FIG. 8.—Patient has made all articles shown. Note saw with handle modeled in wax so that she could use it easily.

In addition to the reconstructive work on the hand, it has been necessary to do extensive work on the neck to free contractures that held the head flexed on the chest.

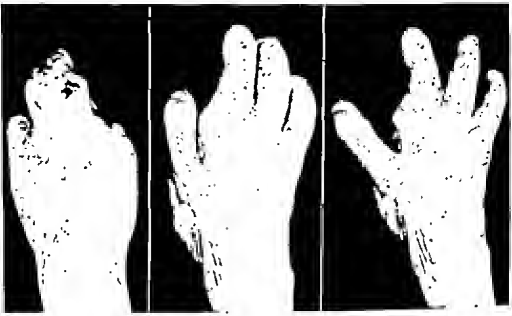

FIG. 1 FIG. 2 FIG. 3

FIG. 1.—The hand has been left a scarred mass, following a severe burn.

FIGS. 2 and 3.—Reconstruction of hand by removing scar to establish joint movement and covering the dorsum with a pocket flap from the abdomen. The space between the fingers was restored with free grafts after the abdominal flap was in place.

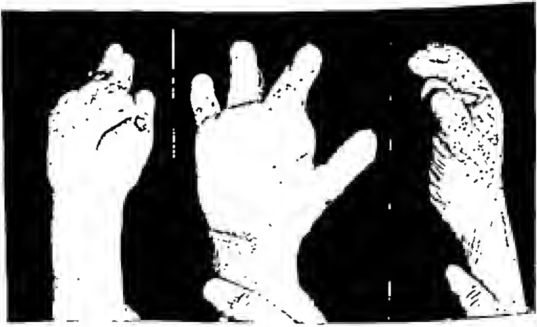

FIG. 4 FIG. 5 FIG. 6

FIGS. 4, 5, and 6.—Different views of same hand.

Radium:

1. To reduce scar tissue, as in keloids

Occupational Therapy.—Occupational therapy, as well as the simplest massage, exercises, and baths, is of real importance for stimulat-

Fig. 9

Fig. 10

Fig. 9—Boy with extensive thick, heavy scarring and contracture of arm to side, and this side of chest and flank.

The arm was entirely freed by release of the scar and complete section of the origin by the pectoralis major and latissimus dorsi muscles and advancement of them higher on the thorax. The resultant defect was grafted with thick split grafts taken from the thighs. An area of more than 150 sq. in. was grafted at one time.

Fig. 10—Severe contractures of axilla (anterior fold and apex) and of neck that has pulled jaw down into an open bite of 1 cm. Note pinch or small deep grafts (applied elsewhere) that have resulted in healing of the area, but not in release of deformity.

The head, neck, and lip were restored to normal position in one operation by excising the scars and covering the defect with thick split grafts.

The arm was freed and the axillary apex and anterior fold were covered with split grafts in one operation.

Massage:

1. To prepare a part for the proposed operation
2. To stimulate the blood supply, as in the base of a pedicle flap
3. To attempt to reduce the amount of scar tissue
4. To loosen up a scar and overcome a tendency to retract or contract
5. To restore function, especially about the joints
6. To loosen the contracture that takes place under skin grafts and flaps

Dry Heat, as from an incandescent bulb, infra-red baker, hot-water bottle, or electric pad:

1. To relieve pain
2. To stimulate the formation of healthy granulation tissue preparatory to a skin graft
3. To improve circulation: (a) to stimulate, (b) preparatory to massage
4. To combat low-grade infection

Hydrotherapy, as local or general baths, local or general salt baths, whirlpool baths, hot wet packs, contrast baths (hot bath 15 min., cold bath 2 min., usually local):

1. To relieve pain
2. To stimulate a healthy bed of granulation tissue
3. To stimulate circulation, as warm saline packs applied about the base of a pedicle flap
4. Preliminary to massage and exercise
5. To overcome infection

Dry Cold, as from ice-bag:

1. To overcome traumatic or postoperative swelling

Ultraviolet Rays, as from quartz light or from direct sunlight:

1. To stimulate healing
2. To improve general condition of patient, especially in children with rachitic tendency
3. To tan, if possible, a skin graft or flap
4. To overcome a low-grade infection, as pimples, preparatory to plastic operation

X-Rays:

1. To overcome (1) low-grade skin infection, (2) almost any type of surface cellulitis, including erysipelas, (3) boils, (4) adenitis, (5) abscess formation, (6) Ludwig's angina, (7) acute parotitis
2. To reduce scar tissue

Extensive Burns

The immediate care of extensive burns necessitates the relief of pain and the treatment or prevention of shock. The immediate local treatment is subject to so many varying possibilities, and the available methods of treatment may be so limited, that no one method can ever be universally relied upon. Any treatment that allows crusts to remain on wounds, under which there is usually a collection of pus, may be sufficient for superficial burns; but for deep burns in which the full

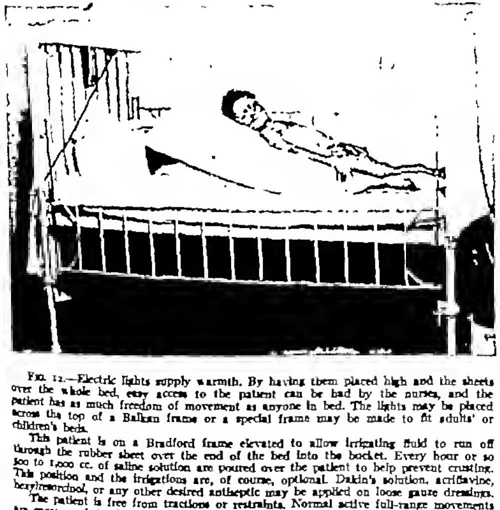

FIG. 12.—Electric lights supply warmth. By having them placed high and the sheets over the whole bed, easy access to the patient can be had by the nurses, and the patient has as much freedom of movement as anyone in bed. The lights may be placed across the top of a Balkan frame or a special frame may be made to fit adults' or children's beds.

This patient is on a Bradford frame elevated to allow irrigating fluid to run off through the rubber sheet over the end of the bed into the bucket. Every hour or so 500 to 1,000 cc. of saline solution are poured over the patient to help prevent crusting. This position and the irrigations are, of course, optional. Dakin's solution, acriflavine, hexylresorcinol, or any other desired antiseptic may be applied on loose gauze dressings.

The patient is free from tractions or restraints. Normal active full-range movements are encouraged (and rewarded) and in this way many secondary contractures may be overcome or avoided even though there may be severe contractore in the burned area.

The change of treatment each day is good for the patient's morale, and as soon as possible, the patient is allowed to be up and around. A wet dressing is preferable at this time and it is left on until the following morning when it is soaked loose in the bath. Grease dressings are rarely used if skin grafting is to be done because grease does not promote very firm granulations. As a substitute for both the wet and the grease dressing, a water soluble jelly to which has been added 2 to 5 per cent of sodium chloride may be used. (Reprinted from the Dallas M. J. (May) 1931.)

ing the patient mentally and for infusing spirit into him. Many patients completely disheartened with a long series of surgical steps may be reclaimed mentally by the instruction and guidance of an occupational therapist.

If the elaborate outlay found in most large surgical clinics is not available, the surgeon will often find the application of these principles directly advantageous in securing surgical results, even if he has to combine the work with his own (Figs. 7, 8 and 11).

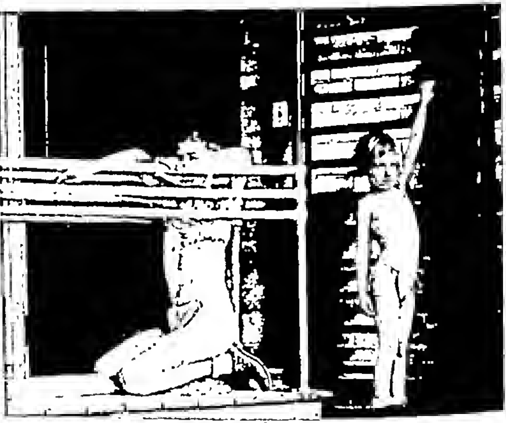

FIG. 11.—Boy and girl of Figs. 9 and 10 shown in physical therapy department.

The boy shows almost full extension of arm and has received great benefit from instruction and training in this department. The nerve supply of the pectoralis and latissimus was not interrupted as evidenced by a good power of adduction of the arm.

The girl is able to close her mouth and raise her head. Her arm movement has been restored to complete extension in one operation.

Over large joints such as the axilla the thick split-skin graft is admirably adapted. Soon after healing is complete, exercise can be resorted to that actively resists the contracture of the base of the graft. Children are excellent subjects and even a simple trapeze will be of great benefit if an established department is not available. Intelligent children are frequently turned loose on their own initiative after the idea of active exercise is explained to them, and they rapidly rehabilitate themselves.

Note that the thighs of both patients from which the grafts were cut are healed. In the girl there is but faint evidence of the wound, although the photograph was taken but 19 days after the operation (Department of Physical Therapy, Shriner's Hospital.)

thickness of the derma has been destroyed, some plan for surgical cleanliness should be employed. No single method is applicable to all cases, but with the general plan of frequently changed hypertonic dressings and with close attention to mechanical cleansing at the time the dressings are changed, most patients will develop clean, firm granulations ready for grafting within four weeks (Figs. 12 and 13).

After sloughed tissue has separated and there is no further toxicity from the burned area, there is left a denuded area that requires restoration of surface covering of sufficient thickness. This restoration should be made as speedily as possible for the conservation of function, health, and comfort. Any treatment or lack of treatment that delays restoration is an economic waste. Especially important is surgical cleanliness for burns of the hand and arm, for here the important tendons and joint capsules are so close to the surface that prolonged chronic infection in granulations over them may result in permanent deformity.

Saline Bath and Dry Heat.—For widespread denuded areas of the body and extremities, the combined use of the saline bath and dry heat is most efficient for cleaning these wounds surgically in preparation for skin grafting. The patient is placed in a warm salt bath for one to three hours a day, and then lies without dressings on a bed, covered with sheeting, to which heat is applied by a string of electric lights above the patient (Figs. 12 and 13).

There are several distinct advantages in this method of care:

(1) The patients are extremely grateful because of their freedom from painful dressings. Patients, both adults and children, who have practically lost their morale from pain and discomfort are frequently made comfortable after 5 to 10 min. in the bath. They may be put in the first time with clothes and dressings left on, and then after soaking for some time, the dressings may be cut loose and removed without pain.

(2) The method is probably the least expensive of any and may be carried out in the home.

(3) After the routine is once established, nursing care can almost supplant the care of the doctor except for daily inspection and necessary changes in care.

(4) Placing the patient unrestrained in the bath and in the bed will both encourage active and passive motion and reduce contractures to a minimum. Restraints in the form of splints, bandages, and loops over extremities can almost universally be avoided. Contracture from surface loss can be remedied satisfactorily only by replacing tissue. The relief obtained from secondary contractures by splinting will be lost in a few hours after removing the restraint.

(5) As soon as the patient is able to be up and around, some sort of dressing must be substituted for the dry heat, and for this hyper-

FIG. 13.—The tub—a portable one—is shown tipped up and without water (for photographing). There is a support for the head, and pads are elsewhere. The bath is kept comfortably warm and up to 5 per cent sodium chloride may be added. Cleanliness is, of course, important, but no attempt is made at sterility. If the patient cannot be easily moved, both bladder and bowel content may be passed into the tub, cleaned out, and fresh saline added. For adults, a long tub is necessary if they are to recline, and the hydrotherapy tub with a canvas sling that the patient lies in about 8 to 10 in. from the bottom of the tub, with the legs and arms free, is satisfactory. For badly burned patients, even though a fatal outcome is expected, this method of care is one of the most comfortable and may be continual. For patients that are first seen with badly matted and stuck dressings, soaking in the bath is probably the best, quickest, and least painful method of removing the dressing and crusts.

This patient was put in for 2 or 3 hr. each morning and frequently slept part of the time.

It is necessary to have a nurse or attendant constantly present for children. [Reprinted from the Dallas M. J. 17: 50-70 (May) 1931.]

Active movement about joints may be started when it is certain the graft can stand it. Deep massage may help to loosen grafts from their bases and also help smooth them out if there is a tendency to wrinkling from contracture of the base. There does not appear to be accurate data on the reasons for variations in the color of skin grafts. Although they rarely "tan" on exposure to actinic radiation, there may be some improvement in color (Figs. 7, 8, and 11).

Pedicle Flaps

Physical therapy of a tedious sort may be necessary for pedicle flaps that have a sluggish blood supply. Light massage with the finger tips along the flap three to six times every five minutes may help replace the inadequate pulse, and, if this is carried out intelligently by the nurse, an apparently doomed flap may be saved. The use of warm wet packs around the base of the flap is valuable; care should always be taken to avoid blistering, and it is best to have the packs tested and applied with the fingers rather than with forceps.

Deep rotary massage of these flaps after they have been completed may free them well from the base, and here again actinic radiation may be tried for color improvement if the flap remains a dead white.

Cleft Lip and Palate

Quartz-light treatment, local and general, has apparently been of great value in some cases that have not withstood operation well. For mild cellulitis and infection of the lips, local radiation has proved especially beneficial.

In infants and children it is necessary to keep the hands away from the mouth and light splints are used to prevent flexion of the forearms.

Speech training is almost as important for good speech as is repair of the palate. With intelligent parents and patients this may be accomplished at home by following simple rules, but most patients do best in class or under the supervision of one who is trained in the work.

Operative Trauma

For swelling following operations (without infection) cold applications simply applied are the most satisfactory. One caution about the face is to avoid putting an ice-bag or any heavy application on an eyelid that is swelling, as a *relatively light pressure may shut off the blood supply and necrosis will result.*

Infections

For infections, hot applications (moist or dry) most frequently relieve the pain and localize the process. Opposition in favor of cold will often be encountered, and since neither process is very well under-

tonic packs of sodium chloride, boric acid, magnesium sulphate, or any desired antiseptic may be used. Then instead of being pulled off, they may be soaked free in the bath each day and reapplied later.

Quartz Light.—Quartz-light treatment of these areas may well be combined in this as in any method of treatment. General radiation two to four times a week will usually be ideal, although heavier radiation of local areas of persistent infection may be indicated.

Exercises and Occupational Therapy.—General physical therapy in the form of active exercises of the hand, arm, or leg muscles is of great advantage. Any occupational therapy, especially with children, has frequently marked the turning point of recovery. The outside limit of activity is encouraged, even if this is nothing more than the knitting of a wash cloth or the cutting out of paper figures. The use of musical instruments or even encouragement to feed themselves may make marked improvement (Figs. 7, 8, and 11).

Skin Grafts

Preliminary Preparation.—The physical preparation of widely denuded areas for skin grafting is essentially as outlined under Extensive Burns. For chronic ulceration of the legs, rest in bed for one to three weeks may be advisable, and may in itself be the main element in a successful skin graft. Added to this there may be elevation or elastic bandaging for the support of the blood column. If the patient remains ambulatory, some type of hypertonic dressing plus a supportive dressing is necessary. Quartz light used locally over infected surface areas may be of great benefit[1] (Figs. 12 and 13).

Fixation of Dressings.—One of the most essential factors in successful skin grafting is applying the dressing with the correct mechanical pressure on it and maintaining it in place. The routine use of damp marine sponges (or some other medium) for obtaining elastic pressure, incorporated in the original dressing of a skin graft, is as important as any single step in the operation. The sponge itself does not supply the pressure but must be held accurately in place and at accurate tension by the bandages.[2,3]

Joint movements about grafts must be restrained by bulky dressings or by wood or plaster splints.

After-Care.—Good gentle mechanical cleansing is important from the start. If time can be taken for it, actinic radiation at the time of each dressing may have a beneficial effect on healing. The dressing is removed and all grease is cleaned from the area. The graft and surrounding area are then exposed directly to the quartz light. Usually the first dosage is 1 minute at 36 inches. The time is increased 1 minute and the distance decreased 1 inch up to 10 minutes at 20 inches.

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For the contraction that occurs under some skin grafts and tends to wrinkle them, we have occasionally found good relief by the use of light exposures of radium, preferably given as soon as the wrinkling becomes apparent.

X-ray and Radium Lesions

The underlying pathology is a destruction of the collagen and an endarteritis of the finer vessels. This is followed by a telangiectasis of the capillaries, which may later become thrombosed, keratosis of the epithelium, and occasionally transition to carcinoma. Since the exciting cause is the x-ray or radium ray, it would seem inadvisable to employ sunlight, quartz light, or further x-ray or radium ray in the treatment of these lesions. However, all the above forms of radiation have been advised and the practice is mentioned here only to call attention to its apparent uselessness. The only solution to the problem of relief of badly or widely involved areas is total destruction by electrocoagulation or electrodesiccation, by the actual cautery, or by sharp dissection. It is preferable to excise wide areas and this usually calls for some method of surface repair, such as the shifting of adjacent healthy tissue or the use of free skin grafts or pedicled flaps.

Repair of Surface Losses of the Hands

The loss of surface covering of the hand results from innumerable types of accidents but most frequently from burns. One of the most crippling deformities results from injury from household mangles, in which there are both a severe burn and a crush. Early determination of the extent and depth of destruction is very important in these cases, and where there is any appreciable extent of skin loss, steps should be taken immediately to clean the wounds and to cover the defects with tissue of suitable thickness. If there is destruction of the full thickness over the dorsum of the hand and fingers and if some form of expectant treatment is instituted in which crusts form on the wound and slowly separate, ultimate healing may occur by spontaneous epithelization. However, the attendant infection and scar tissue formation about the joint capsules and tendons will so limit motion that normal function may never be obtained. Losses on the palmar surface of the hands and fingers do not often result in such permanent damage because the heavy subcutaneous tissue protects the joint capsules and tendons to a marked extent. The surface scar may be extensive, but usually when it is released the tendons will give and the joints will open.

Preoperative Period—Splinting.—During the period of waiting for reconstructive operations, correct splinting and dressing are important. Extreme secondary contractures in either flexion or extension

stood, arguments on both sides may be given for the use of one over the other. As a general rule, heat is probably most effective and is most kindly received by the patient for swelling from infection, while cold is better for swelling from trauma.

For erysipelas and similar types of infection that occur about the head and face during the process of repair of a defect, hot hypertonic applications are used routinely. X-ray radiation in the form of light exposures may be used and excellent results are obtained in many instances.

Chronic furunculosis or pimple formation is a definite contraindication for the plastic repair of any defect because it is an expression of low resistance in general and because the organism, being ready to contaminate any field, may set up an active infection in the operative field itself. Along with other general treatment measures, either x-ray or actinic radiation will be found very useful in clearing up this skin condition.

Scars

As soon as the wound has healed in some instances, active physical therapy may be started to relieve the scar defect. Excellent results may be obtained by the use of actinic radiation, followed by heat (usually dry, as from a large electric light bulb or an infra-red baker). After this, prolonged gentle massage is given. Heat is applied over the scar for 5 to 10 min. Then a lubricant (cocoa butter, for example) is applied and the trained technician starts a gentle stroking massage. As the wound becomes older and therefore firmer, the strength of the massage is increased and should consist of both stroking and kneading. The massage should last for at least 30 min. If possible, it should be repeated daily for the first two weeks and then applied every other day until the scar has been loosened and its deforming appearance overcome, or until no further progress is made.

Surface scars occurring in suture lines or around the edges of grafts present the greatest hindrance to acceptable surgical restorations about the face. It seems that they occur most frequently where they are least desired. Plump or fat children or young adults are the most susceptible, probably because of tenseness and thinness of the skin from distention of the subcutaneous fat. Infection in the suture line during healing, cuts and incisions across the lines of skin tension, and poor approximation are, of course, contributing causes.

Of the many physical agents directed against these scars, radium seems to offer the best help. Capsules of 25 mg. of the element with a screening of 1 mm. of silver and 1 mm. of rubber applied along the scar for one to one and one-half hours frequently suffice. The dose may be repeated once or twice if it seems advisable.

Deep scarring does not respond well or uniformly to radiation, and applying the rays through any considerable thickness of tissue to affect deep scarring is a questionable procedure.

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Preoperative Period—Splinting.—During the period of waiting for reconstructive operations, correct splinting and dressing are important. Extreme secondary contractures in either flexion or extension

deformities and even in subluxation of the phalangeal joints may be largely avoided by gentle dressing in simple splints with the fingers extended or flexed as indicated. If there is loss between fingers, they should be held apart with even a simple piece of gauze used as a splint. Too often where most of the skin of the hand has been lost (the "degloved hand," as used in English literature), the final result is a scarred mass with thin scar epithelium continuous over all the fingers and with function practically nil. This same thing happens in losses in the cubital fossa and in the axilla where the forearm is allowed to attach itself to the arm, and the arm, to the chest wall.

Saline Bath.—If the patient is given a warm saline bath and a small rubber ball or sponge to handle for one to three hours a day, he will probably greatly overcome the tendency to deformity. As the wounds become clean, gentle massage and passive motion may be added while the hand is in the warm saline soak.

Postoperative Period.—After operation, in which binding scars have been excised or released, perhaps joint ligaments have been cut and there has been surface restoration of suitable thickness, a new drive for function must be made, and physical therapy is often put to a severe test.

Splinting.—Splinting is still imperative to overcome joint, joint capsule, and tendon deformity. The main criterion is whether the thumb can be apposed to the fingers, and the next is whether suitable flexion of the fingers for gripping can be established. In practically all cases the wrist should be cocked up if there is any involvement around it. As a working basis, the splints employed by Drs. Kanavel, Koch, and Mason may be taken as a standard.

Massage.—Massage can usually be begun early and should be carried out intelligently over long periods of time. Fifteen to thirty minutes once or twice each day may be used if the force is carefully graduated. The massage may be given during periods of dry heat, or following hot wet baths, and the working time each day may thus be reduced. When joint motion is limited, an important addition to simple massage is to move the joint through its full range of motion and to maintain it in its extreme flexion and extension with gentle force for 5 to 15 min. at a time. Real pain should not be caused, but the force should be stopped just as discomfort is noticed. Instead of being allowed to relax completely, the joint should be maintained in this position, and usually in a few moments some further slight relaxation may be obtained.

Exercises.—Muscle-training exercises may be begun in the simple fashion of closing the hand on a rubber sponge or ball, and activity may be increased rapidly.

Joints and tendons in children respond rapidly and a normal child is likely to adopt the best possible activity if he is given the opportunity of interesting play (Fig. 11).

Occupational Therapy.—Occupational therapy, by supplying the mechanical means and the trained instruction in gross and fine activities, can frequently cause the patients to make rapid strides. A general idea of the problem must, of course, be given to the therapist by the surgeon, together with careful instruction as to the greatest activity desired. If the trained instructor adds her knowledge of diversion to the training, better purposeful results may be expected, and articles of real value may be made by even small children (Figs. 7 and 8).

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CHAPTER THIRTEEN

PHYSICAL THERAPY IN AMPUTATIONS

C. C. Yount, M.D.

In this chapter the amputation stump will be discussed as a functioning member primarily. Surgical aspects will be considered only insofar as they have bearing on function. In amputations of the lower extremity, all stumps, except certain partial foot amputations, require a prosthesis. The stump is a lever which swings the prosthesis in the act of walking, and the efficiency of that lever depends upon many factors other than the mere surgical soundness of the end of the stump: i.e., muscle power in the extremity, condition of joints adjacent to the stump, etc. Not only should a stump be so planned that its function will be as efficient as possible under the surgical condition demanding the amputation, but all means of treatment should be utilized to improve and hasten its early functional use. Certain forms of physical therapy are of great value in the preparation of the stump for early and efficient function.

The need of physical therapy treatment is, of course, greater when healing is delayed on account of infection and other causes, in which case the prolonged inactivity leads to atrophy of the extremity and a tendency to the development of joint contractures.

The "stump end" (end of stump to first joint) is the weight-bearing portion of the stump in below-knee amputation, and the extremity proximal to the stump end must function as the propelling force for the stump end as well as for the prosthesis. The latter averages about five and one-half pounds in weight. It is quite evident, therefore, that the proximal part of the extremity must have normal or, better, above normal power and range of movement, whereas the stump end must inevitably undergo pressure atrophy and must develop weight-bearing tolerance. To state it briefly, then, the aim of physical therapy is to hasten the inevitable shrinkage; to develop weight-bearing tolerance in the stump end, at the same time preventing atrophy and deformity; and to develop power in the proximal part of the extremity.

Stumps That Heal Without Complications

In amputations of the lower extremity in which primary healing has taken place and in which there have been no complications of any kind, actual functional use of the stump can be safely started with a temporary prosthesis from four to six weeks after healing

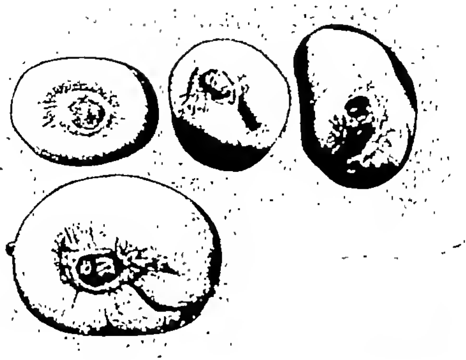

FIG. 1.—Unhealed stumps with terminal scars and edematous soft parts.

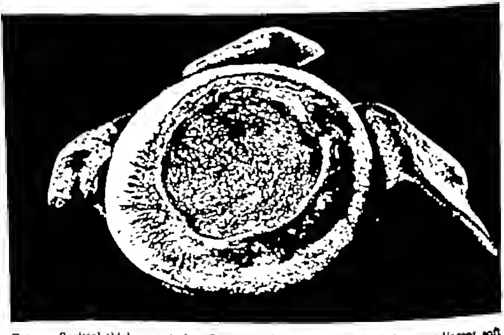

FIG. 2.—Sagittal thigh amputation. Large terminal, infected unhealed area, adjacent soft parts edematous. Notice traction straps turned back.

of the wound is complete. Considerable difficulty in having this part of the program of treatment carried out will be encountered if the surgeon does not have facilities at his disposal for supplying the temporary prosthesis. Most commercial limb-fitters will instruct the patient to wait until the stump has "shrunk" before fitting a finished appliance. It is obvious that, during the period of stump "shrinkage," atrophy is also taking place in the relatively inactive extremity, proximal to the stump end.

The following routine should be followed in this group of cases: Elevate the stump immediately after amputation to lessen swelling and the possibility of hemorrhage. Do not disturb the elevated position for about four days. On the fifth day, remove the stump from the elevated position and passively move the adjacent joints. Repeat this each day until the wound is healed. After healing is complete, have the patient move all joints in the stump extremity through their full range once daily. Apply a flannelette or some type of elastic bandage so as to exert gentle compression of the stump in order to prevent swelling and edema and to begin the process of shrinking, which later must be more vigorously pushed.

Walking with crutches should be started as soon as the general condition of the patient and the surgical condition of the wound will permit. Massage of the unaffected extremity is not necessary in this group, but massage of the stump leg should be started about the tenth day and should be continued daily until the temporary prosthesis is fitted. This massage should be nutritional in type (see Chap. 14), the aim being to maintain muscle tone and to prevent the atrophy of disuse. There is little need for massage in this group after functional use of the stump leg is started.

Compression bandaging of the stump should be continued until pressure atrophy is well advanced—i.e., until the stump is ready for a final prosthesis (Figs. 17, 18, 19). Bandaging at first should be done by the surgeon or an instructed attendant. A flannelette or other type of elastic bandage should be applied in the following manner: First, several folds of the bandage should be pressed over the end of the stump so that slight compression of the end and sides will result. Then circular bandaging should be begun, starting at the very end and gradually compressing the stump circularly as succeeding folds of the bandage are moved proximally. The compression bandage should not be carried beyond the first joint; furthermore, it should not impede free and full movement of the joint. After the bandage is applied, a tight woolen stump sock should be pulled over the bandaged stump to prevent disarrangement of the bandage. The *amputé* himself should be instructed in bandaging his stump. After an appliance has been fitted and the *amputé* has been instructed in the proper use of his appliance, there is little need for physical therapy, as functional use will soon complete the atrophy of the stump end and will quickly develop the proximal part of the stump.

Infected Amputations

Cases in which healing has been delayed, because of infection or for other reasons, offer conditions which demand early coördination of surgery and physical therapy. For this reason it seems advisable to summarize stump pathology and surgical treatment of the infected stump in order to point out the essential physical therapy which should be administered in various forms during the progress of surgical treatment.

Primary Sagittal Amputation.—Experience gained in the war shows that primary amputation in the presence of severe infection at the site of injury, leaving the end of the stump wide open for drainage, should also be done in civil life under similar conditions. In wounds in which there is irregular laceration of the tissue, the amputation need not be done exactly sagittally but may be done quite irregularly, merely by removing all tissue which seems to be definitely avascularized. For instance, if one side of the leg were shattered, leaving a long flap of viable tissue on the opposite side, it would be well to save an ample part of the viable flap, even though the amputation line would be quite irregular. In all cases, as much bone length as possible should be saved at the primary amputation (Fig. 10).

Pathology Referable to Bone.—Osteomyelitis.—The process of sequestration and involucralization, with associated low-grade infection of the adjacent parts, does not differ materially from osteomyelitis under other conditions, except that drainage is, perhaps, more thorough because it is terminal (Figs. 3-6).

This terminal osteomyelitis is one of the chief causes of long-delayed healing, and requires roentgenographic study and special treatment before secondary final plastic operations can be successfully done.

The most common type of sequestrum seen is ring-shaped, usually about one and one-half centimeters in thickness. It is occasionally encroached upon and often more or less concealed by excessive bone production extending down from the bone cortex. In some instances it is seen to be practically encapsulated by new bone formation with a small sinus leading through the latter. In such cases long-delayed healing is to be expected, so that it is advisable to remove sufficient of the encircling new bone to permit the soft parts to fall in and obliterate the dead space.

Excessive terminal bone production in guillotined stumps is the rule. The most common form seen is an irregular mushroom formation with a tendency to spurs on the inner aspect of the femur. Occasionally sharp exostoses, often sharp enough and long enough to cause sufficient pain to warrant their removal, are seen. It is well not to interfere with the terminal bony production unless sequestra are embedded or concealed in it.

Interosseous bony union occurs both in the forearm and leg. In the former, operative interference is indicated only if the forearm stump is long enough to preserve pronation and supination. Treatment consists in removing the connecting bony overgrowth and the

FIG. 3.—Large spur extending into adductor intermuscular plane from short femoral stump

FIG. 4.—Small spurs projecting from both tibia and fibula. This type of spur probably due to stripping up and shredding of periosteum.

FIG. 5.—Smooth healing of leg amputation without any bony change. (From the U. S. General Hospital No. 26, Fort Des Moines, Iowa.)

FIG. 6.—Arm stump, showing marked rarefication of bone from prolonged disuse. Healed without infection.

interposition of muscle. In the leg this condition is helpful rather than detrimental.

Inequality in the lengths of the bones in amputations of the forearm and leg occasionally demands correction. In leg amputations it is preferable, for prosthetic reasons, to have the fibula approximately two centimeters shorter than the tibia. In children one should always amputate the fibula from two to four centimeters above the tibia, because of the tendency of the fibula to grow at a greater rate from the upper epiphysis than the tibia. In certain short below-knee stumps it is possible at the primary amputation to save several inches of fibula but a much smaller amount of tibia. In this case, of course, there should be no sacrifice of fibula.

Pathology Referable to Soft Parts.—Redundant soft parts are occasionally seen. This is usually due to late necrosis of bone or to extensive comminution of bone without equal damage to the soft parts. In the latter instance it is best to save all viable soft parts at the primary amputation, as thereby the later plastic surgery may be greatly facilitated. Except in certain instances, where there has been extensive comminution of bone, redundant soft parts are *prima facie* evidence that more bone has been sacrificed than was necessary. The secondary removal of soft parts for surgical or prosthetic reasons should not be decided upon until the necessity for, and the possibility of, utilizing them in connection with osteoplastic methods to increase the length of the stump have been considered. Bone grafting to increase the length of the stump is a well-recognized and valuable procedure and is especially applicable to short below-knee stumps.

Tender nerve ends are seen most frequently in amputations of the upper extremity, and occasionally in those of the lower extremity. They seldom make themselves manifest until an appliance has been worn, so that in the treatment of unhealed stumps it is safest to assume that every nerve which is palpable may give trouble, and its treatment is indicated at the time of secondary plastic procedure. Simple high division after crushing and ligature seems to give results equally as good as those obtained with more elaborate neuroplastic methods.

Preoperative and Nonoperative Treatment of Infected Stumps

In a preliminary report of experiences in treating the first five hundred amputations at Walter Reed Hospital, the author advocated an ultraconservative policy in the surgical treatment of unhealed stumps. It seemed at that time that, by the use of skin traction and other nonoperative measures, healing could be obtained in a reasonable time, and that secondary operative surgery of the stump could be dispensed with in the majority of cases. Subsequent experience showed that it was possible to obtain complete healing in guillotined and other in-

fected stumps, but that a very long time was required, and that the resulting scar was not sufficiently tolerant to the usual traumas of an appliance to be practical. It was also found that many either actually required an alteration in site or that a limited amount of bone could be removed without damaging the stump from a functional viewpoint, so that, finally, plastic methods designed to obtain a firm closure with freely movable skin were employed usually before cicatrization was complete.

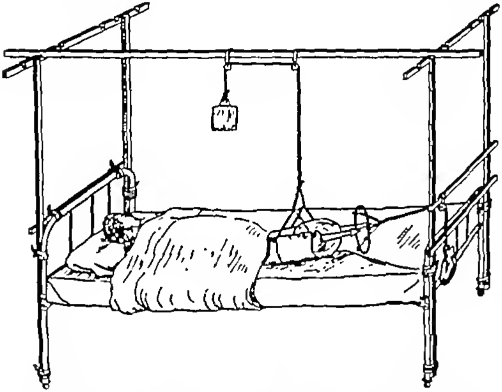

FIG. 7.—Stump traction in recumbency. The adhesive straps which extend from the stump to the ring should be so placed that the flaps will tend to coapt when traction is made upon the skin. The pulley should be arranged so that it can be lowered and raised at will, in order gradually to combat flexion deformity. The foot of the bed should be raised six inches. The amount of weight can best be determined by observing the pull on the stump after weight is applied. Stump traction should not be so strong that redundancy is created at the end. In case stump traction is desired with the patient ambulatory, a short Thomas splint may be substituted for the apparatus shown in this picture.

Preoperative Routine.—SURGICAL REST.—The importance of surgical rest in the treatment of large infected stump wounds cannot be too strongly emphasized. Nothing is gained in hastening prosthetic treatment to the point of applying temporary prostheses before the stump can be considered surgically sound. In the majority of cases it is best to treat all cases requiring secondary surgical procedures in recumbency until wounds are in the desired condition for operation. It has been noted repeatedly that wounds which remained practically

stationary under ambulatory treatment would promptly heal in recumbency.

Skin Traction.—Skin traction is used routinely both in recumbent (Fig. 7) and ambulatory treatment (Fig. 9). In the former case, direct extension is accomplished by means of adhesive strapping, or with a pulley and weights, and in the latter, by means of counterextension with a modified Thomas splint.

Traction is, of course, most effective if applied immediately after amputation. Its effect then is actually to reduce the extent of the uncovered area. If it has not been applied early, and if the skin has

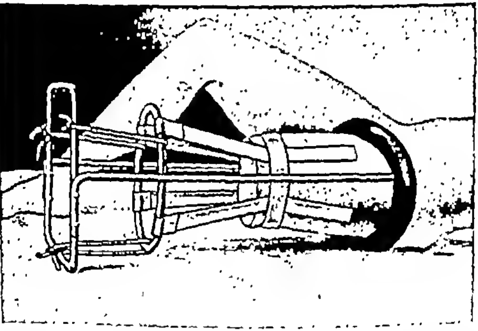

Fig. 8.—Stump extension with a modified Thomas knee splint. A Thomas knee splint is cut down and a 9-in. square riveted to the side bars 11 in. beyond the end of the stump. An 8-in. circle of aluminum is attached by gauze and glue to the skin of the stump so as to be 6 in. distal to the cut surface. Extension is made from the ring to the square by either tapes or rubber bands. The square acts as a pedestal and also serves for the attachment of the extensions. (Adapted from Sinclair.)

been allowed to retract and to become adherent to the edges of the unhealed area, traction does not tend to reduce the unhealed area materially, but it relieves tension at the edges of the ulcer, thus favoring healing. It is particularly helpful in subsequent plastic operations because it renders the skin more redundant. In some cases in which there is wide retraction of the skin in short stumps, it seems best to dissect the skin free and then apply traction for a time before attempting a final plastic closure. The influence of stump traction in the prevention of joint contractures is obvious.

Wound Antisepsis.—The Carrel-Dakin routine treatment should be used in all infected stumps as long as the unhealed area is large, concave, and discharging pus freely.

Massage.—Massage of the terminal part of the stump is beneficial in several ways. In healed stumps with small scar areas adherent to the bone, much can be accomplished toward loosening the scar and improving its circulation and thus increasing its tolerance to trauma. In unhealed stumps, massage of the skin adjacent to the scar area assists in removing edema and generally improving the circulation as well as in rendering the skin free and more redundant preparatory to the final plastic surgery.

FIG. 9.—Ambulatory traction for below-knee stump.

Attention to Adjacent Joints.—At each dressing the stump should be moved fully in the opposite direction to that in which a contracture is most likely to develop. Insofar as it is possible, the recumbent position of the patient and the adjustment of traction should be such that the usual contractures will tend to be prevented. (Special treatment of each joint will be mentioned in the discussion of Amputations and Their Prosthetic Requirements.)

Secondary Stump Surgery.—Attempts to perform final plastic closures of infected or guillotined stumps soon after the injury result in a high percentage of failures. The most important factors in the failures are: (1) the poor general condition of the patient following the more or less severe trauma and the subsequent emergency operative and postoperative treatment; and (2) latent infection, which is present not only in the terminal granulating area, and, in many cases, in the terminal portion of the bone, but also in the lymphatic channels and lymph nodes, for a considerable distance proximal to the unhealed area.

It is not justifiable to attempt plastic closures or reamputations adjacent to the unhealed area until at least five or six months have elapsed from the time of the original injury. An attempt was made, in army hospitals during the war, to establish definite preoperative indications by bacterial counts from the wound surface, but it was apparent that this method of control was not reliable, as it gave no indication of the extent of latent infection in the lymphatic channels further up the limb. It was found better to depend upon observations referable to the clinical appearance of the stump and the general condition of the patient.

As long as a stump remains swollen, boggy, and edematous, it will be found that there is latent infection present which will defeat attempts at plastic closure (Figs. 1 and 2). The disappearance of the edema is usually coincident with the improvement in the general condition of the patient and the local appearance of the unhealed area. Final closure should not be attempted until the skin and subcutaneous tissue are soft, dry, wrinkled, freely movable, and absolutely free from streptococcus and the field count is reasonably low for other less virulent pyogenic organisms.

Operative Treatment of Unhealed Cases

Group I.—In this group are stumps in which a limited amount of bone may be removed without diminishing the ultimate functional value of the stump.

The question of bone length requires careful consideration in every case, and there are times when it is justifiable to preserve it by sacrificing ideal conditions in the soft parts. But, on the other hand, in perhaps the majority of the sagittal amputations, little is lost in ultimate function by removing a limited amount of bone and much may be gained by the additional freedom allowed to eradicate more thoroughly the potential latent pathology in the terminal portion of the infected stump. Before attempting final plastic closure in cases in this group, all indications previously pointed out regarding the proper time to operate should be present, except that the actual size of the unhealed area can be disregarded.

METHOD OF OPERATING IN GROUP I.—The unhealed area and the scar are completely covered with a gauze sponge which has been saturated with tincture of iodine. Incision is now made in healthy skin one-half centimeter from the edge of the scar. The incision should follow the general contour of the scar area and no attempt should be made to form specially designed flaps. The distal skin edge is clipped to the iodized gauze as the incision is being made, thus completely isolating the terminal infected area. The skin and scar are then dissected distally and separated from the muscle at the place where the muscles are attached to the bone. Usually this will be above the area of new bone production and well away from the unhealed area, usually one or one and one-half inches. Incise the periosteum just within the area of fibrous tissue which extends a short distance distal to the actual muscle fibers. Saw the bone at this point. If the preoperative treatment has been properly carried out and the scar area is not excessive, it will now be possible, by careful disposition of the skin, to cover the end completely. If it is found that the available skin is not sufficient, additional bone or muscle may be removed. It is better to avoid cutting through the muscles and deep vessels. The nerves are found usually by palpation and should be pulled down and severed through a small longitudinal incision in the muscles. The wound should be drained for 48 hours through a posterior stab wound. This type of drainage is preferable because: First, it gives the best drainage, being dependent; and second, in the event primary union is not obtained, sufficient drainage is afforded through the posterior opening to prevent the incision line from separating. Primary union in the incision line is often obtained and maintained in the presence of profuse purulent discharge, which is satisfactorily taken care of through the posterior drainage incision.

GROUP II.—In this group are stumps which are already too short and which will not permit additional sacrifice of bone.

It is imperative that at least six to eight months have elapsed since the initial injury and that in addition to the preoperative requirements already enumerated, the wound be completely cicatrized or that the unhealed area be very small and practically sterile.

METHOD OF OPERATING IN GROUP II.—The scar should be completely removed. The bone should not be disturbed unless there are exostoses which are likely to give trouble. Palpable nerves should be treated as described in Group I. The aim of the operation is, of course, to cover the stump completely with healthy, freely movable skin. This is practically never possible without special plastic procedures. The short, below-the-knee stump is the most common example of this group. The limited amount of skin may be made more accessible in several ways: (1) by removing the fibula, (2) by removing the major portion of the muscles of the calf of the leg. A triangular section with

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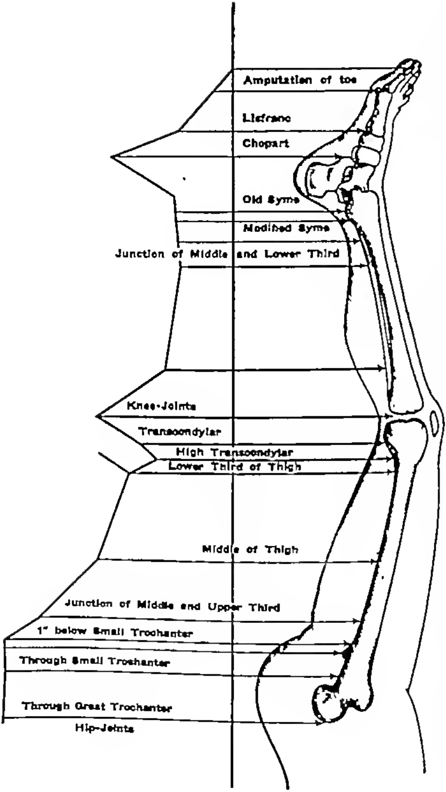


FIG. 10.—Graphic representation of the relative functional value at different levels of bone section. The curve falls rapidly in partial amputation of the foot. The bottom is at Chopart site. It rises sharply to the Syme level and falls away in the lower third. It then gradually descends as bone length diminishes from the lower third up to within three inches of the knee joint. It rises to the point of highest efficiency at the transcondylar site, then falls away gradually in the thigh up to within three inches of the joint where the bottom of the curve is reached and maintained, including all amputations up to disarticulation.

the base external gives the best skin mobilization. The muscular tissue directly attached to the bone should not be disturbed and care should be taken to leave sufficient blood supply; (3) by using the following methods of skin plastic procedures which have been found successful:

1. Double lateral pedicle
2. Double oval swing
3. Single oval swing
4. Distal pedicle transplant

Group III.—This group includes those cases in which sagittal amputations had been done at a site considerably distal to the ultimate secondary site to be selected. Amputation through the ankle joint is an example. In this case, the Syme amputation could not be considered, as sufficient soft parts are not available, so that the next choice of site would be through the junction of the middle and lower third of the leg. Other examples would be sagittal amputations one-half inch below the knee joint, requiring a formal transcondylar amputation.

In this group it is possible largely to disregard pathology referable to the terminal part of the stump and to proceed with the final amputation much earlier than in the other groups. In all cases, however, it is advisable to adhere strictly to the rules regarding delay until the general condition is sufficiently improved to withstand a major surgical procedure and to those regarding edema of the soft parts and associated lymphangitis and lymphadenitis. The treatment in this group is formal reamputation.

Operative Treatment in Group III.—A reamputation is equivalent practically to a primary amputation under ideal conditions, and necessarily involves careful consideration regarding the site and its influence upon the ultimate functional result. The value of a stump in terms of function can be correctly estimated only when the stump and its prosthesis are considered as a complete functioning unit. It follows, then, that in order to choose the proper site one must consider carefully the comparative value of prosthetized stumps.

Amputations and Their Prosthetic Requirements

Lower Extremities.—Partial Amputations of Foot.—Amputation of toes, metatarsophalangeal amputations, and transmetatarsal amputations result in good function. All the length possible should be saved. It is a mistake to do a textbook amputation if more bone can be saved than is specified in the classical type of amputation. All bone length possible should be saved in the metatarsus. It is justifiable to attempt to preserve bone length in the metatarsus at the expense of perfect skin covering and immediate sound healing. All such cases require a distal pedicle transplant later, but the delay and the extra

surgery necessary are well compensated for in function. A scar on the foot healed by granulation, directly overlying bone, will inevitably ulcerate and cause intermittent disability. Every effort should be made to obtain a dorsal linear scar, with the ends of the bones well covered with a plantar flap. The use of the distal pedicle transplant will obviate the necessity of reamputating partial foot stumps with an intolerant scar.

Lisfranc's Amputation.—Lisfranc's amputation gives reasonably good function only in case dorsal flexion of the foot is preserved by anchoring the dorsal flexors of the toes to the ends of the bones. The same general surgical considerations apply here as described for metatarsal amputations. The only appliance necessary for this, as well as

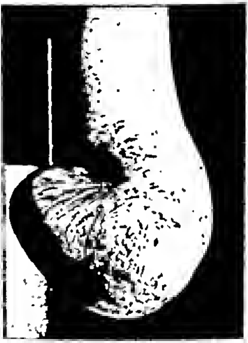


FIG. 11.—Chopart stump, showing usual deformity. (Huggins.)

for the former, is a filler for the toe of the boot and a steel inset in the sole to prevent turning up of the toe.

Transtarsal Amputation.—Transtarsal amputation, distal to Chopart's site, seems preferable to a formal Chopart's amputation, as proper balance of the dorsal and plantar flexors of the foot is better preserved. However, the same prosthetic objections apply to this amputation as to the Chopart.

Chopart's Amputation.—Chopart's or mediotarsal amputation usually results in poor function for surgical as well as for prosthetic reasons (Fig. 11).

(*a*) The type of injury requiring a Chopart stump seldom leaves sufficient plantar flap to permit the scar to be placed well on the dorsal surface.

(*b*) Equinus deformity of the stump eventually develops in spite of efforts to preserve foot balance by tenoplastic procedures. As equinus develops, the scar, which is usually terminal and poorly vascularized, is pressed upon, and end bearing, the greatest asset of this stump, must be forfeited.

The stump is too short properly to anchor the necessary fill in the forefoot, so that constant friction between the toe fill and the end of the stump takes place, usually resulting in ulceration and consequent disability. Lack of stability in the toe of the appliance prevents the necessary forward thrust in walking, so that slight limp is invariably present. In many Chopart stumps it is necessary to anchor the forefoot by extending a steel rod to the ankle joint and connecting this by a joint to a steel upright which is laced to the leg. This appliance requires a special shoe with a very unsightly ankle.

The percentage of surgical successes in Chopart stumps is so low and the prosthetic difficulties so great that it is not a justifiable amputation unless it is intended that a simple elephant boot be worn continually instead of the articulated appliance. This point is mentioned because there are undoubtedly cases in which occupational considerations should predominate over the esthetic.

The importance of preserving muscle balance in partial foot amputations requires special attention. A plaster cast should be applied with the foot at right angles in slight inversion. The cast should be bisected so that it can be removed and replaced easily. Passive and active movement should be started as soon as healing is complete. The dorsal part of the cast may be used as a night splint for several weeks, during which time massage of the leg muscles is being carried out.

Pirogoff's Osteoplastic Amputation.—The added risk of an osteoplastic procedure is not compensated for in any way, as the per cent of total end bearing in the Syme amputation is quite as high as in the Pirogoff. The added length in the Pirogoff requires that the other shoe be raised at least an inch to make up for the space required for the ankle movement in the appliance. This amputation is not recommended.

Syme Amputation.—The chief advantages noted in the perfect Syme amputation are that it is total end bearing, and that the length of the limb is approximately preserved, so that the patient can walk in the nude without his appliance, and that either the straight boot or the appliance with an articulated foot can be worn with reasonably good function.

Unfortunately, the per cent of perfect Syme stumps is not high. Failure is usually attributed to one or more of the following causes: sloughing of the plantar flap due to cutting the pedicle too narrow; lateral displacement of the flap; sawing of the bones at a right angle

to the terminal axis of the tibia, rather than at a right angle to the long axis of the leg; making the bone section too near the joint to allow space for the mechanism of the artificial ankle.

Functionally, a perfect total end-bearing Syme is a satisfactory stump. The choice between this amputation and one at the ideal site in the leg involves an analysis of the occupation and habits of the patient. A laborer is better satisfied with the Syme amputation because he can wear a straight, nonarticulated boot during the working hours, and he is less likely to be dissatisfied with the bulky, unsightly ankle mechanism when dressed up than a professional man, for example, would be. In women, leg amputation is preferable to the Syme for esthetic reasons.

Amputations of Leg.—*Lower Third.*—Nothing is gained by the additional bone length in the lower third of the leg, as excessively long leg stumps interfere with proper shaping of the ankle portion of the artificial leg, and may actually interfere with the ankle mechanism. Poor vascularity is the rule in the lower third of the leg. This results in poor or delayed healing or in ulceration later in life.

Junction of Middle and Lower Third.—Amputation at the junction of the middle and lower third of the leg has proved to be the preferable site in the leg. The essential points in technic are (1) long anterior and short posterior flaps, the scar line being posteroterminal; (2) suture of a thin flap of muscle and fascia over the bone ends to prevent adherence of the skin to bone; (3) fibula divided one-half inch higher than the tibia; (4) beveling of the tibial crest; (5) drainage when necessary through a small stab wound in the middle of the posterior flap.

The appliance for this amputation is simple, durable and shapely. If the fitting is proper, disability is scarcely discernible. Stump tolerance to the appliance is quickly acquired and the functional result is very gratifying to all concerned.

In amputations of the leg above this ideal level, every effort should be made to preserve all bone length possible. When the amount of bone length that can be preserved with good soft part coverings is three inches or less, it is justifiable to sacrifice ideal conditions as regards the soft parts, if bone length can thereby be increased. It was generally considered, early in the last war, that it was not justifiable to attempt to amputate below the knee if the amount of bone length possible to be saved was less than three inches. Subsequent surgical and prosthetic developments warrant a revision of this opinion. In these cases the leverage may be increased to the point of utility by removing the fibula; cutting away practically all of the muscular tissue on the back of the stump; and severing the inner hamstring. Special study and experimentation in the prosthetic treatment of short stumps carried out at various clinics gives promise of increasing the functional utility of stumps of not less than two inches in length, so

that it seems best to defer reamputation at a higher level until surgical attempts to increase bone length or to increase leverage by other methods have failed.

The prevention of knee flexion contractures requires special attention in short, below-knee stumps. In addition to the usual measures, the following procedures are necessary in very short stumps: (*a*) Muscle or fascial suture over the bone end should be done with the

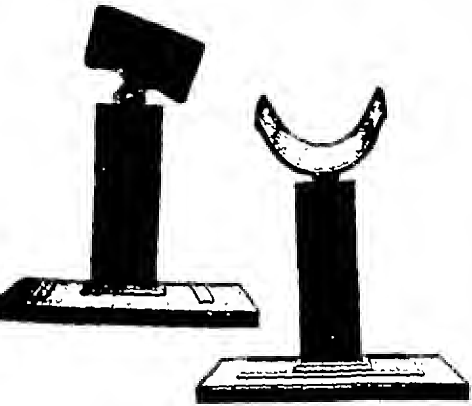


FIG. 12.—A simple support or leg-rest used to support the leg in below-knee amputations. The support on which the leg rests is made of heavy metal covered with leather and is attached by a joint to a wooden upright. The wooden upright is supported in a hollow, built-up, wooden block, which is secured to a wooden base. The support rests on the table on which the patient lies and is covered with sterile draperies before the sterilized leg is placed on it. It is placed under the leg, just below the knee joint, holding the leg extended, away from the table, and is accessible on all sides. It may be placed higher up behind the knee in short below-knee stumps.

knee in full extension (most amputations below the knee are done with the knee flexed on a sand bag or stump rest (Fig. 12)). (*b*) The biceps should be cut or, better, stripped up subperiosteally. (*c*) A cast or posterior splint or traction should be applied until healing is complete and muscle balance is reëstablished.

AMPUTATIONS OF THIGH.—If it is not possible to amputate through the leg two inches from the knee joint (bone length), the next best

site is the high transcondylar. This excludes knee-joint amputations, all osteoplastic amputations at or immediately above the knee joint, and low transcondylar amputations. All of these are too long to allow the use of the standard artificial knee action and require a cumbersome and faulty mechanism outside the clublike stump. Osteoplastic amputation (Stokes-Gritti) offers nothing in function superior to the high transcondylar to compensate for a rather high per cent of surgical failures and the prosthetic difficulties already mentioned. In the high transcondylar amputation, the bone section is made at the point where the condyles begin to merge with the shaft. It is important to keep within the spongy bone below the beginning of the medullary cavity proper. A long anterior flap of skin and quadriceps tendon is used. The scar is placed well to the posterior, away from the end-bearing surface. Surgical failures are few, and total end bearing results in practically all cases. Ample space is left to place the standard artificial knee action in the proper place.

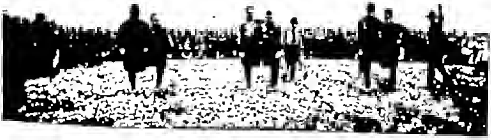
Above the site for the high transcondylar amputation every effort should be made to save all bone length possible to a point two inches below the lesser trochanter. All stumps having bone length of from two to four inches below the lesser trochanter require a pelvic band. This is an objectionable feature so that a special effort should always be made to preserve more than four inches, if possible. A stump having bone length of less than two inches below the lesser trochanter does not have sufficient leverage to operate the thigh appliance on account of the disposition of the soft parts adjacent to the joint. The only choice then is to give a stump suitable for the so-called hip-joint appliance.

From a prosthetic and functional viewpoint the classical disarticulation at the hip is not preferable to amputation through the neck. The latter is much more quickly and easily performed. The mortality is lower and the resulting stump is better adapted for the fitting of an appliance. Unless there are definite pathologic reasons for complete disarticulation, as in new growths, amputation through the neck is preferable.

Contractures.—In the short thigh stump contractures will develop unless preventive measures are instituted immediately after amputation. The usual deformity is flexion and abduction. This deformity interferes markedly with good functional use of an appliance, because it is necessary to throw the lumbar spine into marked lordosis in order to put the artificial foot squarely on the ground.

The following measures are effective in preventing this deformity:

(*a*) Surgery: The anterior and posterior groups of muscles should be sutured together and the fascia lata should be sutured to the adductor group. This aids in preserving balance between the abductors and adductors and gives a more effective terminal attachment for the gluteus maximus, part of which is inserted into the fascia lata, thereby increasing its mechanical advantage and enabling it to establish at least partial



Figs. 13, 14, 15.—Stump drill. During the World War, when groups of amputations were being cared for, stump drill was found to be beneficial for increasing the range of motion and developing muscle power.

balance with the strong iliopsoas which has been undisturbed at its relatively high insertion into the lesser trochanter.

(*b*) Physical therapy: As soon after the operation as the general condition of the patient will permit, he should be turned face down for at least one hour each day with a sand bag or hard pillow under the end of the stump, which is forced into hyperextension. If this is not possible, stump traction should be applied in such a manner that extension of the hip joint will be maintained. After the stump is healed, passive and active movements in the direction of extension and adduction should be done at the massage period, and at other definite periods (Figs. 13-16) daily until the stump is being used functionally.

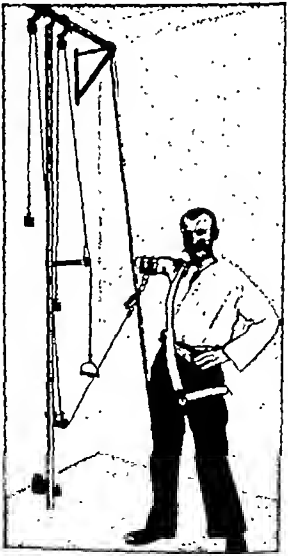
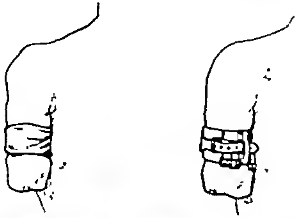


FIG. 16.—Numerous types of mechanotherapy to develop the musculature of short-arm stumps may be devised. This illustration shows a simple type which is practical and was found useful.

The correction of long-standing flexion-abduction contractures is best accomplished by surgery, rather than by physical therapy alone. Division of the fascia lata, followed by vigorous stretching, manually and by mechanotherapy apparatus, will correct moderate degrees of flexion. In the more persistent ones, Scutter operation for hip flexion should be done. It will seldom be necessary to free the attachment of the iliopsoas, as the deformity is usually not a true flexion contracture.



FIGS. 17, 18, 19.—End of stump rendered clublike by the use of a constricting band. The clubbed end facilitates the attachment of apparatus. This is very useful in work appliances.

Upper Extremity.—The rôle of the appliance in the functional utility of stumps of the upper extremity is considerably less important than in the lower extremity. In fact, it is debatable whether, in the

case of single amputations of the upper extremity, appliances are of sufficient value to constitute a deciding factor in the selection of site. The patient who has lost an arm is eager for his appliance (1) because he wants to mask his disability, and (2) because he hopes it will be functionally useful. To his great disappointment, he soon realizes that it is, indeed, a poor substitute for either purpose. Approximately 60 per cent of the individuals who have suffered the loss of a single arm do not find existing prostheses sufficiently useful to compensate for the inconvenience of wearing them. The exception is that they wear them occasionally for esthetic purposes. The following conclusions regarding sites are based upon the use of American prostheses, and do not involve a consideration of surgical and prosthetic experimental work carried out in certain American and various foreign clinics since 1921, as opportunity for exhaustive study and evaluation of the results has

Fig. 20.—Radical surgical procedures are justified in attempting to restore the prehensile function to the hand. This shows a successful transplant of a part of the great toe to replace the thumb.

not been possible. (In 1920-21 the author visited all important amputation centers in England, France, Germany, Austria, and Italy under the auspices of the American Red Cross in order to observe and attempt an evaluation of the various methods of treatment developed during and after the war. Official reports of this study are available in the files of the American Red Cross in Washington.)

Amputation in Hand.—In primary surgery immediately following the trauma, nothing more should be done than débridement, trimming the devitalized tissues, and establishing thorough drainage, the question of site being totally disregarded. The prevention of contractures of the fingers by proper splinting demands special attention from the beginning.

In the secondary surgery of the hand, radical alteration in the site of amputation is seldom advisable. The usual conditions demanding treatment are sluggish, unhealed areas, associated with localized osteomyelitis, or tender and adherent scars with tendency to deformity, especially when on the flexor surface of the joints. The latter condition usually demands special plastic procedures, in order that the scar may be displaced by freely movable tolerant skin. The distal pedicle transplant gives the best results where it is important that no bone be sacrificed. Usually a portion of a phalanx of any of the fingers, except the

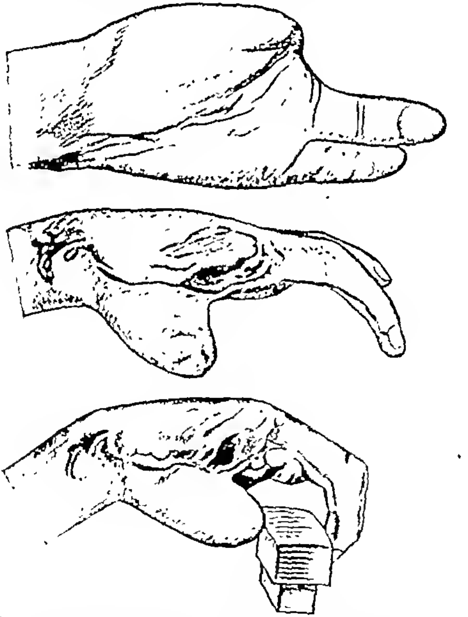


FIG. 21.—Prehension made possible by plastic reposition of metacarpus of thumb.

index and the thumb, can be sacrificed without serious functional damage in order to obtain good soft-part covering (Fig. 20).

The loss of the thumb or any part of it constitutes a serious disability. A badly-damaged thumb, with loss of muscular power or ankylosis, or both, is preferable to any mechanical substitute. Heroic efforts at reconstruction of the thumb are justifiable (Fig. 21).

Prostheses for amputation of individual digits are seldom useful, except for the thumb. They are most useful if the thumb is amputated or if all except the thumb are gone, as apposition is made possible by the prosthesis in either case. If a sufficient part of any of the fingers remains to make active apposition possible, a prosthesis is seldom worn, except for esthetic reasons.

Transcarpal Amputation.—Transcarpal amputation is preferable to amputation at the wrist even though there is an adherent terminal scar. The latter can be repaired by distal, pedicle skin transplant.

Wrist-joint amputation is distinctly preferable to amputation higher up, as pronation and supination are better preserved, and the fitting of a hand or work appliance is facilitated by the more or less clublike end of the stump, which permits the elimination of much attachment harness.

Amputation in Forearm.—Amputation in the forearm should be done as low down as possible. In the lower third, circulation is often poor, but usually not troublesome enough to warrant amputation higher up solely on this account. Primary amputation should seldom be done higher up for this reason, and reamputation should not be considered unless all efforts to improve the circulation have failed. The importance of preserving pronation and supination warrants special attention to surgical details, i.e., careful treatment of the periosteum to avoid shredding and consequent overproduction of bone, and the interposition of muscle to prevent bony bridging.

No matter how short a forearm stump may be, it should not be sacrificed, as in the majority of cases a forearm stump is more useful without a prosthesis than an upper-arm stump either with or without an appliance (Figs. 22-25). Forearm stumps should never be shortened to correct inequality in the length of the bones. Tender scars or objectionable scars should not be corrected for any reason by the sacrifice of bone, but by plastic methods involving the soft parts only. The presence of redundant soft parts is an indication for plastic methods to increase length rather than to remove redundancy.

Amputation in Upper Arm.—Transarticular and transcondylar amputations are generally considered objectionable from the standpoint of existing prostheses, because the fitting is difficult and there is inconvenience to the patient in applying and removing the apparatus. Moreover, the artificial joint must be placed lower than on the normal arm. Experience shows, however, that in single amputations, less than

20 per cent of upper arm *amputés* wear appliances. Of these, it is reasonably safe to assume that the majority are those wearing a practical (work) appliance rather than an esthetic one. The newer practical appliances are more securely fitted with less harness if the bony prominence of the condyles is present, so that before deciding upon the sacrifice of the condyles, a careful analysis of the requirements of each individual case is necessary. Above this level, all bone length possible should be saved.

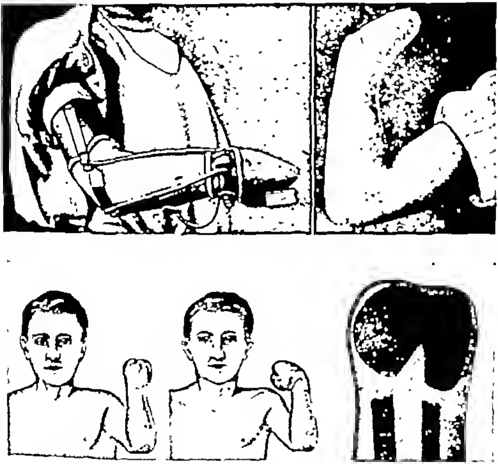


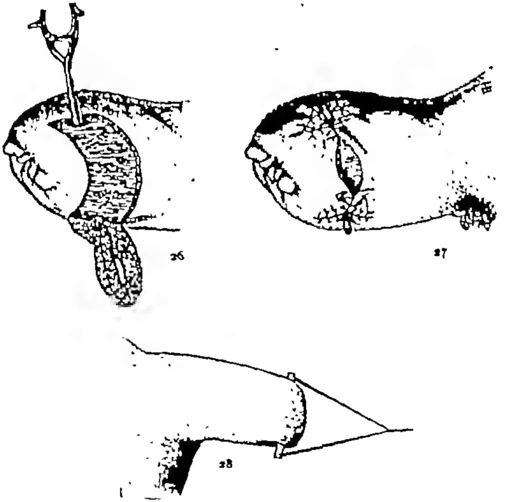
FIG. 13-15—Plastic pseudarthrosis club motor. Valuable in work appliances.

Cinematization of Amputation Stumps

In July, 1918, the report of a special committee, directed to investigate the question of cinematization, was available to those engaged in amputation work. The conclusions of this committee were, briefly, that cinematization could not be recommended except as an experimental procedure, because it was still in the trial stage, and that it should not be attempted unless adequate facilities were available for pursuing the

experimental prosthetic work necessarily associated with it. Three cases were cared for in the base hospitals in the United States and two patients with cinematized stumps were returned from overseas. In none of these cases was the final functional result a distinct improvement over that obtained with the usual methods. Two were failures and required excision of the tunnels. Lack of success was due to the failure of coördination of the surgical, physical therapy, and prosthetic treatment; to the frequent transfer of patients; and perhaps, in a measure, to the breaks in follow-up coincident with frequent changes in personnel after the Armistice.

The admitted functional deficiency of all prostheses for the upper extremity stimulated surgeons, before and during the war, to try to utilize muscle power in the stump by connecting it more effectively to the prosthesis, so that the muscle power could be used to operate the



FIGS. 26–28.—Cinematic amputation. Fig. 26 shows rectangular area of skin freed and sutured into a tube. Tube is then drawn through muscle belly. Fig. 27 shows denuded area covered, rubber tube left in skin tunnel. Fig. 28 shows method of attaching skin tunnel to appliance.

terminal part of the appliance (Figs. 26-28). Cinematization, as proposed by Vanghetti, was tried and enlarged upon during the war. It has a limited field of application.

(1) Cinematization should be considered only in double amputation.

(2) The vocational reëducation plan should be thoroughly worked out, in each case, in advance of any cinematization efforts to improve stump function. After the trade, its tools, and the operation of the tools by the available stump have been studied, cinematization should be considered, but only individually and selectively in each case. It is essential that the surgeon make an individual and personal study of the functional possibilities of the stump under consideration. Physical

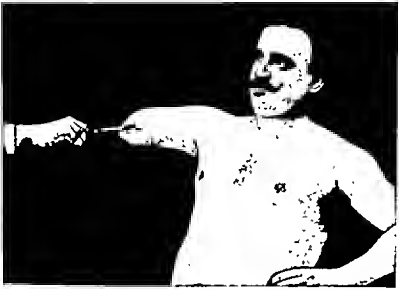


FIG. 29.—Cinematization-muscle power in the tunneled muscle motors must be developed before an appliance is worn. Furthermore, skin tolerance in the tunnel must also be developed. This may be done by passing a metal rod through the tunnel, the rod being attached to a chain or strings which are connected to a weight and pulley, or force may be exerted manually as shown in this illustration. The chief value of this type of cinematization is that it facilitates the attachment of a work appliance instead of serving as an active motor to activate the end tools or the hand.

therapy really begins in earnest after the tunnels or club motors are healed surgically. The aim of physical therapy, of course, is to develop tolerance in the tunnels or clubs; to build up the cinematized muscle groups by means of massage, and active muscle movements by means of direct attachment of the muscle motor to weights and pulleys (Fig. 29).

SPECIAL POSTOPERATIVE TREATMENT

Traction.—In all stumps in which there is even moderate tension, traction straps should be applied in the operating room. In undrained

cases it is best not to apply weights until the following day, unless tension is marked. If applied at once, traction seems to create dead space and favors the accumulation of clot. In addition to the advantages of traction previously mentioned, there seems to be no doubt that it adds to the comfort of the patient by preventing muscular spasm and that it is instrumental in preventing postoperative hemorrhage in the same way.

Blood drainage should be removed in 48 hours. In case secondary hemorrhage occurs with ballooning of the flaps, it is best to remove the sutures, clean out the clot, and reapply traction. Secondary infection is frequent in cases in which special attention has not been given to the elimination of dead spaces and in those in which secondary hemorrhage occurs.

Use of Provisional Appliances

Amputations of Lower Extremity.—In all stumps of the lower extremity, with the exception of partial amputation of the foot and the Syme amputation, a portion of the stump is called upon to function in a manner entirely new and for which it is poorly adapted, that is, weight-bearing. Radical physiologic changes necessarily take place in the weight-bearing portion of the stump, i.e., pressure atrophy of the soft parts; increased tolerance of the skin to lateral pressure from the encasing socket of the appliance; development of balance and sense of position; and tolerance to pressure on, and adjacent to, bony prominences. The other important task of the stump leg is propulsion of the limb and its appliance. In spite of the fact that the artificial limb is not so heavy as the amputated part, more power is required to swing it on account of its comparative inertness. Increased difficulty in balancing undoubtedly adds to the demands made upon the muscular power of the proximal part of the stump leg. Of vital importance is the preservation of normal muscular power, or better, the development of increased muscular power, in the proximal part of the stump leg.

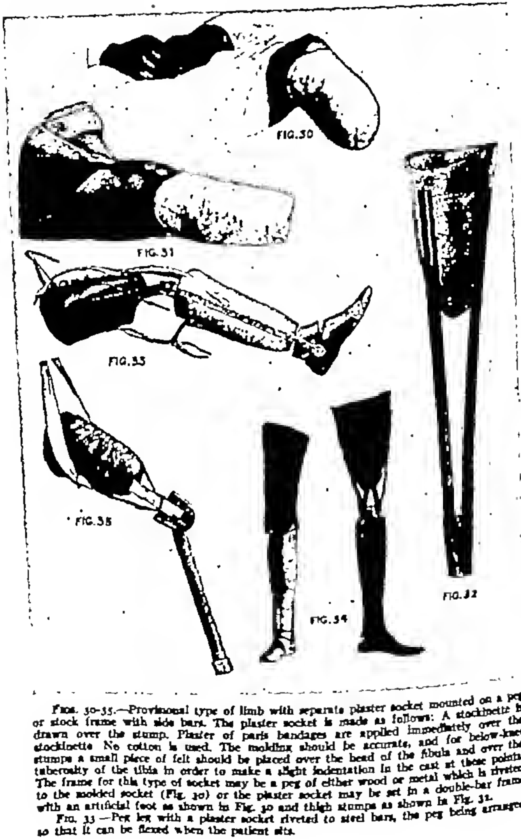
Inasmuch as certain definite physiologic changes must take place both in the stump and in the proximal part of the leg before a stump can be considered functionally fit for a permanent appliance, it is clearly the duty of the surgeon to use all methods at his disposal to hasten these changes and to obtain a good functional as well as a good surgical stump before a permanent appliance is used. The development of provisional appliances, which can be made cheaply and quickly under the supervision of the surgeon, has been instrumental in bringing about coördination of the surgical and prosthetic treatment of the stump. This coördination existed in most amputation centers during and after the war, but most surgeons have not appreciated the importance of supervising the early functional development of the stump, and have reverted to the former practice of dismissing the patient to commercial limb makers after surgical healing is complete.

Principles of Fitting.—Weight bearing in the case of below-knee amputation is distributed as follows: cone bearing (lateral surface bearing), bony-prominence bearing (head of tibia, tuberosity of tibia, fibula below head), partial thigh surface bearing (thigh cuff), and, in a certain percentage of cases, end bearing. In a finished appliance, the stump is encased in a solid shell, which is molded or carved to fit the stump in such a way that all the bearing points and surfaces are used to a variable degree. The physiologic changes in the stump will depend largely upon the predominating type or types of bearing chosen in a particular case.

Cone and bony-prominence bearing, with slight partial thigh bearing, are applicable to most leg stumps, except the stump resulting from the Syme amputation. Pressure atrophy is rapid and marked, consequently repeated remolding of the socket is imperative. End bearing diminishes pressure atrophy of the stump. In amputation of the thigh, bony-prominence bearing (ischial tuberosity), cone bearing, and in certain cases, end bearing, are utilized. Bony-prominence bearing predominates, so that pressure atrophy of the stump is slower and less marked than in leg stumps.

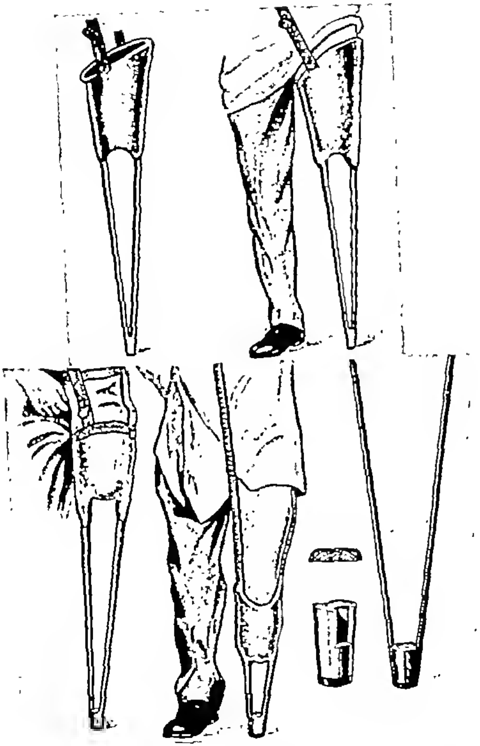
There seems to be no doubt that end bearing is possible in a fair percentage of stumps, and that success in obtaining it is largely dependent upon faithfulness and persistence in carrying out the necessary preliminary measures to increase the tolerance of the end of the stump. Experience seems to prove that a definite distinction must be made between total and partial end bearing, and that in certain instances *total* end bearing may not be desirable, i.e., in long, below-the-knee stumps. Cone and bony-prominence bearing give nearly perfect function. If end bearing is attempted in these stumps, there is a certain lack of adhesion between the appliance and the stump and the gait is not so good as with cone bearing. In thigh stumps of moderate length, total end bearing is not preferable to ischial and cone bearing for the same reasons. There is little doubt that *partial* end bearing is always an advantage. The following stumps, in addition to partial foot amputations, are especially well adapted for end bearing: (1) the Syme stump; (2) short below-knee stumps, and (3) stumps resulting from a transcondylar thigh amputation. The section in each of these is through spongy bone, which seems to give a more tolerant end-bearing surface. Each is clubbed more or less on the end, thus favoring proximal methods of attachment of the appliance and avoiding the maladjustment of the appliance mentioned above.

Qualifications of Provisional Appliances.—An ideal provisional appliance should possess, in the main, mechanical features similar to those in permanent appliances. The socket should be of solid material and should be molded or carved in the same accurate manner as in a permanent one. A provisional appliance which merely shrinks the soft tissues of the stump, and does not develop the tolerance of the bearing

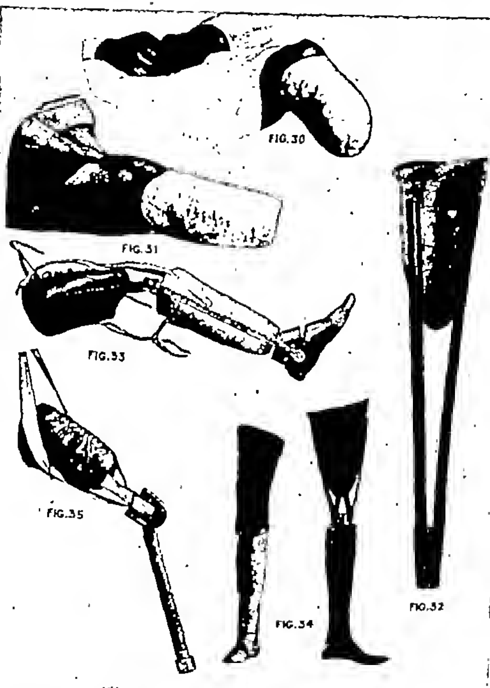


FIGS. 30-35.—Provisional type of limb with separate plaster socket mounted on a peg or stock frame with side bars. The plaster socket is made as follows: A stockinette is drawn over the stump. Plaster of paris bandages are applied immediately over the stockinette. No cotton is used. The molding should be accurate, and for below-knee stumps a small piece of felt should be placed over the head of the fibula and over the tuberosity of the tibia in order to make a slight indentation in the cast at these points. The frame for this type of socket may be a peg of either wood or metal which is riveted to the molded socket (Fig. 30) or the plaster socket may be set in a double-bar frame with an artificial foot as shown in Fig. 30 and thigh stumps as shown in Fig. 32.

FIG. 33.—Peg leg with a plaster socket riveted to steel bars, the peg being arranged so that it can be flexed when the patient sits.



FIGS. 36, 37.—Simplest type of peg leg. The frame part may be made of wood or metal. The socket is made of plaster of paris, and the strap is of simple webbing. The strap goes across the opposite shoulder. This type of peg can be made in any hospital. In case difficulty is encountered in obtaining the wooden part of the frame, a crutch may be used for this purpose. It will be noted that the frame is incorporated in the plaster socket and is not fixed by rivets.



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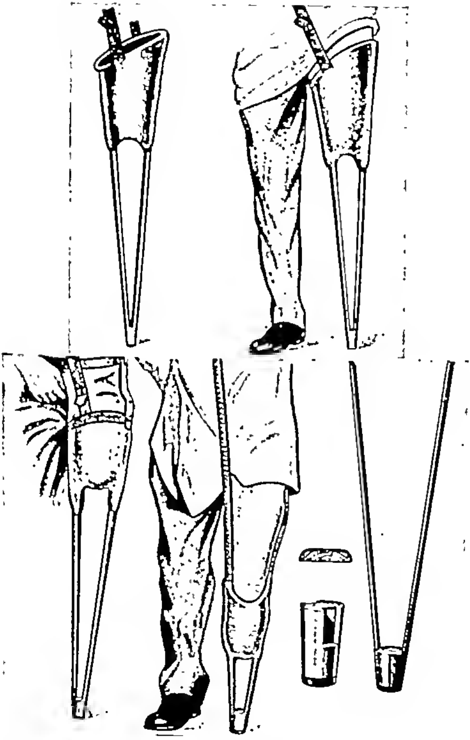

FIGS. 36, 37.—Simplest type of peg leg. The frame part may be made of wood or metal. The socket is made of plaster of paris, and the strap is of simple webbing. The strap goes across the opposite shoulder. This type of peg can be made in any hospital. In case difficulty is encountered in obtaining the wooden part of the frame, a crutch may be used for this purpose. It will be noted that the frame is incorporated in the plaster socket and is not fixed by rivets.

points and surfaces that will be called upon to function in a proper permanent appliance, is not efficient. The provisional socket must be one which can be remolded frequently and comparatively inexpensively. In a certain percentage of cases, it is not only desirable but necessary to change the shape, as well as the position, of the socket. A complete change of socket rather than a reshaping is sometimes necessary. This feature is important in all cases in which there is more or less malposition of the stump, the malposition improving with the use of the appliance.

Types of Appliances—Various types of *temporary* appliances may be used. In most of them the socket is made of plaster of paris and the framework of wood or metal. The various types are shown in accompanying illustrations (Figs. 30-35).

The recent *amputé* is usually most concerned with removing his physical deficiency as soon as possible from an esthetic rather than from a functional standpoint. Pegs (Figs. 36 and 37) and the cruder types of temporary appliances are strenuously objected to by many patients. If the surgeon explains the physiologic and economic reason for the use of temporary appliances, the assent and the coöperation of the patient will be obtained in most cases.

An attempt was made in the United States Army to utilize a provisional leg, which in all respects looks like a finished leg. Of necessity, it was adjustable as to length, foot position, and socket. The socket adjustment was accomplished by means of molded plaster of paris sockets which were made on the patient and then set into the stock frame of the provisional appliance. New plaster molds were made as the stump shrinkage progressed.

In addition to meeting the esthetic requirements more satisfactorily than the peg appliance, this type offered the advantage of quantity production and quicker fitting.

In thigh amputation and in about 85 per cent of the cases where there was sufficient bone length to operate the ordinary thigh leg, this latter type of provisional leg was entirely satisfactory (Figs. 38-40). Most of the remaining 15 per cent fell into the class of excessively long stumps. It was not possible to fit these on account of interference of the mechanism for the adjustment of length. The greater part of the weight rests on the tuberosity of the ischium, and accurate cone bearing is relatively unimportant; consequently the cone fitting does not need to be very exact. In leg amputations, the task of fitting this type of leg was much more difficult (Fig. 41). Bony prominences are more numerous and less tolerant to weight bearing. Consequently, the bony-prominence fitting must be more accurate and a great amount of weight bearing must be allotted to the cone fitting. For this reason, the latter must be more precise.

In order to meet the requirements of the more difficult cases which could not be fitted with the original model of the stock appliance, a more versatile type was developed and the stock parts (framework)

manufactured in quantity, in a variety of sizes, the only essential difference from the original model being that a carefully-molded plaster socket was made and riveted to the side bars.

The plan generally adopted in all amputation centers is to fit the stump with a temporary appliance as soon as healing is complete, but not to hasten the prosthetic treatment at the expense of a good surgical result (Fig. 42). The appliance is worn at first to the limit of tolerance, special care being taken not to damage the soft parts. The part of the appliance which encases the terminal part of the stump, commonly called the socket, is changed and refitted as pressure atrophy pro-

FIGS. 38-40—Stock provisional appliances used in army hospitals during the War. The main body of the limb is made of fiber with connecting parts of metal. A variety of sizes and lengths was supplied in stock. Adjustments for length were made both below and above knee, merely by sawing off as much fiber as was necessary. The socket was fitted by means of an adjustable leather cuff. This was later abandoned and molded plaster of paris sockets were made over the stumps and then set into the fiber frame of the limb.

FIG. 39—Patient wearing below-knee limb of this type. The plaster socket is resting between the artificial limb and the patient's left leg. It appears dark because it has been shellacked to protect it from perspiration.

FIG. 40.—Below-knee stump with plaster socket.

points and surfaces that will be called upon to function in a proper permanent appliance, is not efficient. The provisional socket must be one which can be remolded frequently and comparatively inexpensively. In a certain percentage of cases, it is not only desirable but necessary to change the shape, as well as the position, of the socket. A complete change of socket rather than a reshaping is sometimes necessary. This feature is important in all cases in which there is more or less malposition of the stump, the malposition improving with the use of the appliance.

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culature of the proximal part of the leg well developed. The stock provisional appliance is sufficiently durable to last from eight months to one year. Three to six months' preliminary prosthetic treatment is usually sufficient to prepare stumps for the permanent appliance.

Partial amputations of the foot, Syme stumps, end-bearing thigh amputations and disarticulations of the hip do not require provisional appliances, as a rule. In these stumps the fitting is difficult, and there is so little change in the stump compared with changes in stumps in which cone and bony-prominence bearing predominate, that there is no reason to delay the permanent fitting.

Amputations of Upper Extremity.—The use of provisional appliances in amputations of the upper extremity does not seem to be so

FIG. 41.—First temporary appliances for short thigh stumps in double amputation. It is advantageous in double amputations of the thigh to have the temporary appliance very much shorter than the normal length, as it is very difficult for these patients to regain the sense of balance and equilibrium. As skill in walking with the short pegs is developed, the length may be increased. (Courtesy Letterman General Hospital, San Francisco, Calif.)

necessary from the standpoint of fitting as in amputations of the lower extremity. The physiologic changes in the stump caused by the use of the appliance are not marked enough to require frequent refittings and an exact fitting is not so necessary as in lower-extremity stumps. The chief advantages in provisional fitting are that (1) immediate fittings are possible, which would not be the case in time of war, if permanent appliances were supplied by the artificial-limb industry; (2) an opportunity is given to coördinate the surgical, prosthetic, and physical therapy treatment and to carry out a reëducational program

gresses. Three changes are usually required. Deformities and surgical defects of the stump, i.e., bony spurs, latent infection, tender nerves, etc., will be readily discovered and should be treated during this preliminary prosthetic treatment. Stumps should not be fitted with a permanent appliance until they are surgically sound, pressure atrophy of the weight-bearing portion well advanced, and the propulsive mus-

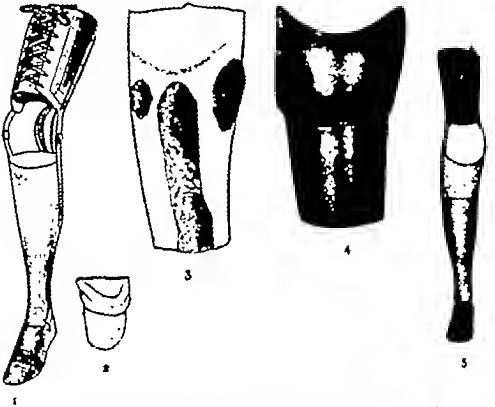


FIG. 41.—The United States Army temporary below-knee prosthesis.

1. The temporary below-knee fiber set-up as supplied by the Minneapolis Artificial Limb Co. The side steels are removed by cutting the copper rivets which secure them to the vulcanized fiber shin piece. The shin piece can be shortened to desired height by sawing off its top, made larger or smaller by removing the copper rivets posteriorly which secure the overlap seam of the prosthesis. There is ankle and toe motion, the foot is of wood, uncovered and not painted.

2. A plaster socket is molded to fit the stump and secured in the upper end of the fiber shin piece where it is made fast. This type of socket is short-lived but easily changed as shrinkage occurs.

3. A plaster model of the stump with areas built up with felt where pressure cannot be borne. The line around the top indicates the future top of the bucket. Around this corrected model of the stump three layers of thin harness leather are molded. They are glued together and sewed posteriorly with wax-end. The last layer of leather extends only part way down the bucket, acting as a shoulder which supports it in the fiber shin piece.

4. The finished molded leather bucket, ready to be secured to the fiber shin piece. It is of rigid construction.

5. The temporary below-knee prosthesis complete, aligned and ready for use. The bucket is securely fixed to the upper end of the fiber shin piece, the side steels have been adjusted and riveted in position. The upper end of the shin piece, the leather bucket and side steels are covered with calfskin, which is fixed in position with glue or cement. (Orthopedic Shop, Walter Reed Hospital.)

attachment plate in which a hand, tools, or any type of hook or other useful device could be used interchangeably, was adopted. The metal parts were manufactured in quantity and issued to amputation centers. Sockets were made of leather and the work of fitting was done in appliance shops. Workmanship and exactness of fitting were probably not equal to those obtainable in the open market, but the arm served the purpose as a provisional appliance as well as could have been expected from any single type of appliance obtainable (Fig. 43).

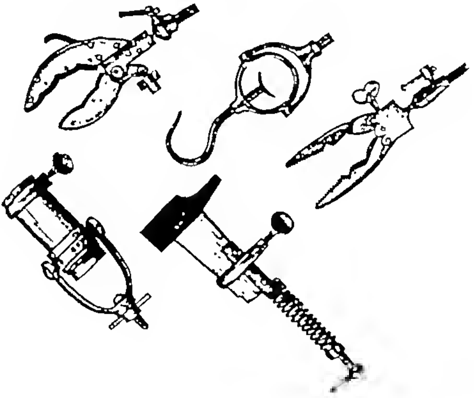


FIG. 44.—In the provisional arm with universal end plate, any number of attachments may be devised and inserted. This illustration shows a collection of tools for agriculture, namely, the claw, pincers, the sleeve for handled tools, the open hook, and the hammer attachment.

Occupational Therapy and Reëducation.—LOWER EXTREMITY.—In lower extremity cases, the actual use of the appliance in walking is the only reasonable means of occupational therapy, so that if regular tasks are to be assigned, they should be those which require walking under varying conditions, i.e., steps, irregular terrain, etc. In double amputations, considerable assistance and instruction are necessary at the start. At first, crutches and quadruped progression must be resorted to. Later, a double-rail walking platform with grades and steps

which is often more helpful than the appliance per se; (3) surgical defects of stumps become apparent while the patient is still under control of the surgeon and can be corrected at once; (4) the patient has an opportunity to learn something about appliances and is thus able to make a more intelligent choice of a permanent appliance.

The first provisional appliances used in the army were of a simple design and were rather crudely made. The socket was of plaster of paris. In the end of the socket was incorporated a metal clamp to hold various implements. Later an inexpensive arm, with a universal end-

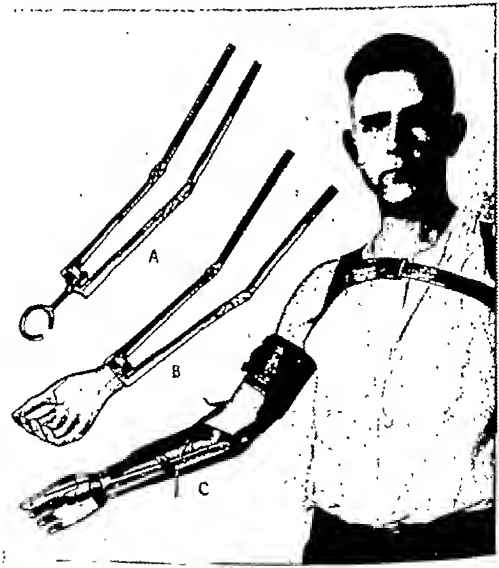


FIG. 43.—Stock provisional arm of combined type for hand or numerous types of end attachments. (A) Unfinished metal frame with universal end joint with simple split ring inserted. Any type of tool may be devised and inserted in this universal end plate. When the arm is to be used purely for esthetic purposes, the hand is inserted in the end plate as shown in (B) and (C).

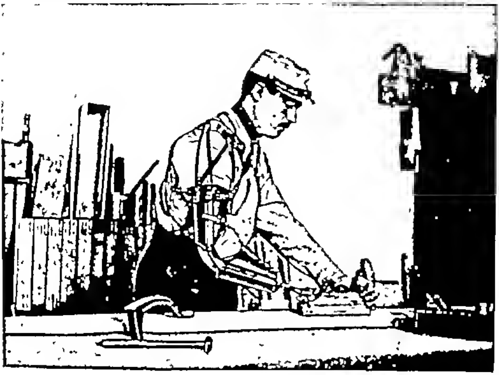


FIG. 47.—An adaptation of a plane with the appliance.

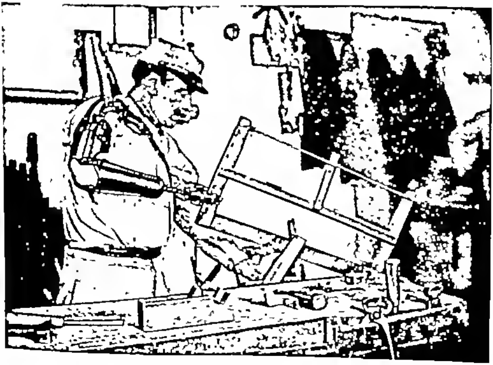


FIG. 48.—Adaptation for saw.

FIG. 45.—During the development of the musculature of the stump, occupational therapy may be considerably facilitated by making adaptations of tools and work appliances to fit the stump rather than by depending entirely on the apparatus which is fitted to the stump. An example of this type of occupational therapy is shown in this illustration. Adaptations of sport implements (i.e., golf stick, ping-pong racket, billiard cue) were successfully made in army shops during the War. These are very valuable during the development of the musculature of the stump and are a helpful factor in improving the mental state of the patient.

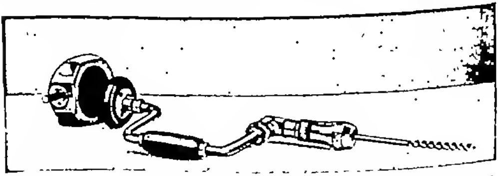
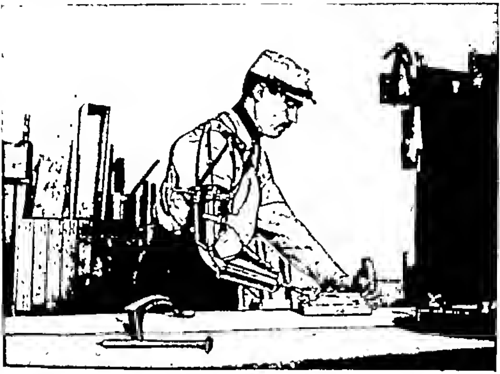


FIG. 46.—An adaptation to enable a person with an amputated limb to use an auger.



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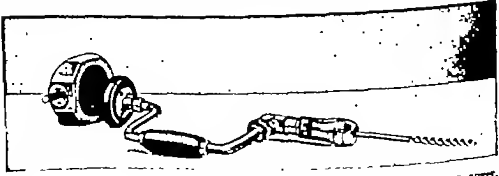


FIG. 46.—An adaptation to enable a person with an amputated limb to use an auger.

may be attempted without crutches. Finally, independent walking, preferably under the instruction of a person with an amputation, is attained.

UPPER EXTREMITY.—Occupational therapy is made possible, first, by the early fitting of temporary appliances (Fig. 44) of such type that many varieties of tools may be inserted in a universal end-attachment; and, secondly, by the adding of attachments which will permit the stump arm to be used as an auxiliary, without an appliance (Figs. 45-50), thereby bringing it into functional, if not vocational, use, for therapeutic purposes.

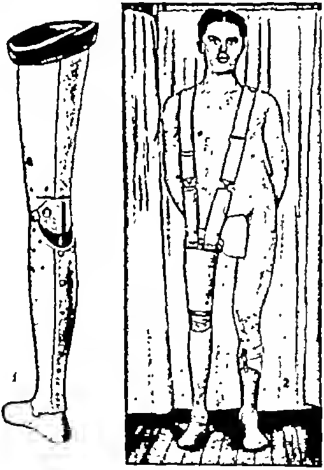


FIG. 51.—The United States Army temporary thigh prosthesis, ischial-bearing.

1. The temporary fiber prosthesis without suspenders as supplied by the Minneapolis Artificial Limb Co. This prosthesis is adjustable and readjustable as to length and alignment, as to size of thick bucket, and as to the distribution of weight on nonweight bearing and weight-bearing points. This temporary prosthesis has the same knee, ankle and toe motions as the permanent type of prosthesis. The bucket is of rigid type but adjustable.

2. The temporary fiber, ischial-bearing prosthesis fitted and properly aligned, with suspenders attached (Courtesy Orthopedic Shop, Walter Reed Hospital.)


Fig. 49.—Adaptation for hammer and file.


Fig. 50.—Adaptation for handled tools.

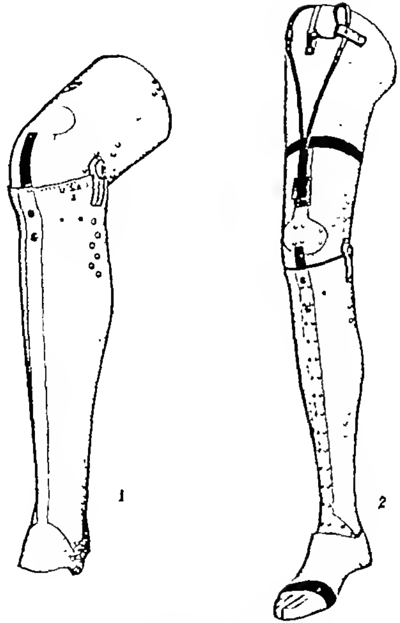


FIG. 53.—The duralumin prosthesis.

1. Duralumin "set-up" consisting of shin piece, knee joint, and knee block made of duralumin. The prosthesis is completed for the ischial-bearing type by adding a wooden thigh bucket and wooden foot as shown in 2. The "set-up" weighs two pounds and two ounces. The completed prosthesis weighs about four pounds

2. The duralumin ischial-bearing prosthesis with willow bucket. Shoulder straps are shown entering the anterior surface of knee block for knee control. The duralumin leg has become very popular on account of its light weight. (Courtesy J. E. Hanger, Inc.)

There is no doubt that there are insurmountable problems connected with the replacement of hand function by the mere substitution of a prosthesis. Real progress in improving the function in arm amputations depends upon: first, reëducation of the remaining hand in single amputations; and, secondly, reconstructive surgery in double amputations, together with individual development of special appliances for particular trades.

In teaching patients who have undergone recent amputation how to take care of the acts of personal necessity—dressing, etc.—arrangements should be made to secure the services of an experienced person who has undergone an amputation, as it is impossible for an unamputated person really to aid as an instructor. This plan was followed in

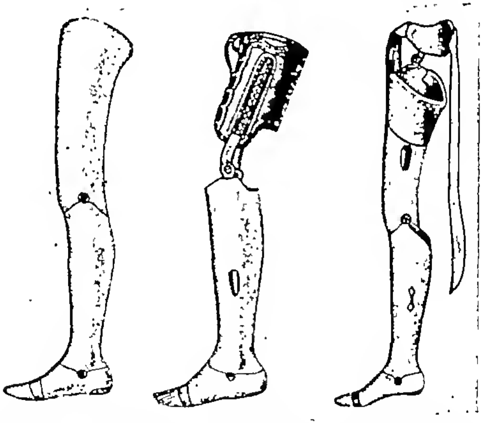
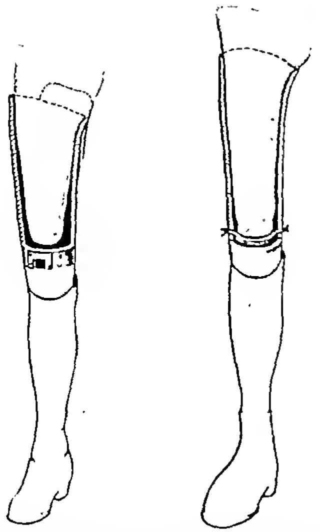


FIG. 52.—Willow legs for ischial-bearing thigh and below-knee amputations without suspenders. The feet are made of willow and wood allowing toe motion and articulate at the ankle joint with the shin piece which is made of willow. The knee joint of the thigh prosthesis is of the cordless type. The sockets of both the below-knee and thigh prostheses are machine made. The legs are covered throughout, including the feet, with rawhide which is painted with waterproof, flesh-colored cement.

The willow socket is at times modified and a "leather-back" socket made, which can be used for stumps with a length of more than six inches. The willow is cut away and a rigid leather back substituted. The leather-back socket is more comfortable to sit in and is easier on clothing than the solid wooden socket as the leather is softer and tends to flatten out when the amputé sits down, as does the normal thigh. (Courtesy J. E. Hanger, Inc.)

Upper Extremity.—Finished appliances for the upper extremity as offered by the commercial market should be considered only from the standpoint of general utility, as such arms are seldom of much value vocationally. They are useful in carrying, as the fingers can usually be locked in flexion or set permanently in flexion with a movable thumb;



FIGS. 55, 56.—Ischial bearing is the predominant type of bearing in all amputations of the thigh (Fig. 53), except transcondylar, which is shown in Fig. 8. In the latter, note that hammock is suspended in order to permit end bearing. In some finished appliances, the terminal part of the socket is shaped and the hammock is not used.

and they are useful as an auxiliary in single amputations. Practically all arms offered have similar features—namely, a rotating wrist and a movable thumb, which apposes to fixed fingers by spring action, the fingers being in slight flexion. The thumb is usually operated by a cord extending to the opposite shoulder.

the army and should be used by all surgeons who are doing amputations.

PERMANENT APPLIANCES

Lower Extremity.—PARTIAL FOOT AMPUTATIONS.—The appliance for a partial foot amputation requires a fill of cork and metal reënforcement in the toe of the shoe to keep it from turning up. Chopart amputation requires, in addition, anchorage in the form of a molded leather lacing, with side steels extending up to the knee. Syme amputation requires an ankle joint and side bars, either lateral or anteroposterior.

BELOW-KNEE AMPUTATIONS.—The socket is made of willow and is shaped by routing with a drawknife. It is anchored to the foot by steel

FIG. 54.—Types of prosthesis made for partial foot, the Chopart, and the Syme stumps. (Courtesy E. H. Erickson Co.)

bars, which are set into the wood. The entire limb, except the joints at the ankle and the knee, is covered with rawhide. Lateral steels extend above the knee. To these are attached a leather thigh cuff, which is laced to the thigh (Figs. 51-54).

THIGH AMPUTATIONS.—The main body of the limb is made usually of willow or aluminum (Fig. 8). In either case the socket is of willow. The knee action is either automatic (spring control) or is controlled by a strap which goes over the shoulder. The weight-bearing is on the tuberosity of the ischium in most thigh stumps, except the transcondylar (Figs. 55 and 56). In the latter, total end bearing is possible.

Redundancy.—Many stumps become redundant after prolonged use of an appliance, so that the skin hangs in folds. Fissures form between the folds and become the seat of various types of dermatitis. If redundancy is marked, and fissures and dermatitis are continually interfering with the functional use of the limb, it is best to perform a plastic operation to correct the redundancy rather than to temporize with local treatment.

Ulceration.—When patients pass middle life, ulceration near the end of the stump is very common. Frequently the ulceration is due to

Fig 57.—Method of using crutches in the case of an arm stump.

the original pathology for which the amputation was done, such as Buerger's disease, diabetic gangrene, senile endarteritis, etc. In many of these cases, the more recent procedures recommended for the improvement of low vascularity in the extremities should be tried before reamputation is considered—namely, perivascular sympathectomy, ganglionectomy, intravenous saline injection.

Nerve Bulbs.—Tender nerve bulbs, of course, should be removed if they interfere with the use of the appliance.

In amputations above the elbow, a joint is supplied at the elbow and flexion is accomplished by a forward swing of the stump. In upper-arm stumps, of course, attachment to the shoulder is necessary. The problem of vocational appliances in amputations of the upper extremity should be worked out in each individual case, and the appliance should be so designed as to be an auxiliary to the remaining arm in the daily work of the individual.

Care of the Stump

The minor ailments of the stump and difficulties with the socket of the appliance seldom come to the attention of the surgeon, as he usually does not see his patient after an appliance has been fitted. The limb fitter, being eager to please and hold his client, who, of course, is a potential customer for the rest of his life, attempts to give advice on all questions regarding the stump. Due credit for this service should be given to fitters, whose advice is usually helpful, as the majority of them are, themselves, wearers of appliances, but it frequently happens that definitely indicated treatment of the stump is delayed and disability prolonged by withholding medical counsel. Surgeons should insist on following their amputation cases until the permanent appliance has been worn for at least a year, as many stump troubles will appear during that time.

Variation in Size of the Stump.—Usually at the time a permanent appliance is fitted, the stump has not thoroughly "shrunk." In order to avoid frequent changes of the socket, adjustment for the shrinkage is accomplished by adding stump socks. Stump socks are supplied in wool and silk-wool and can be obtained at any appliance house. All stumps should be protected with well-fitting stump socks when the appliance is being worn. Frequently patients are at a loss as to why the artificial limb will fit one month and not the next. As a rule, the explanation lies in the variation of the size of the stump, which increases or decreases as the patient gains or loses weight. Usually, in the morning, some difficulty is encountered in properly fitting the stump into the socket of the appliance, due to the fact that the stump has enlarged slightly during the night.

Chafing.—Early in the functional use of the stump, considerable difficulty is encountered because of chafing of the skin at the points where pressure is exerted. Later, callosities may develop at the same points. In below-knee stumps, these points are under the head of the fibula, on the tuberosity of the tibia, and along the inner surface of the head of the tibia. Treatment of this condition consists in proper local care of the chafed area and remolding of the interior of the socket at intervals.

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Sensations in Amputated Part.—Shortly after amputation, a very high percentage of patients will complain of pain, numbness, paresthesia, etc., in certain parts of the amputated limb. As a rule, it is not necessary to take these subjective symptoms seriously, as it is not long before they are forgotten by the patient.

Use of Crutches

Unless the patient is supplied with a reserve artificial limb, it is inevitable that a fair portion of his time must be spent using crutches while repairs are being made. All persons who have undergone amputations use crutches when the appliance is not worn, as in bathing, etc. It is well for the surgeon to give every patient who uses crutches simple instruction in their use. The weight in crutch progression should be borne chiefly on the hands, and the axillary rest should take only part of the body weight. In the forward thrust of walking, most of the weight should come on the hands. When the patient stands, he will usually allow most of the weight to come on the axilla, thereby giving the hands a rest. If the crutches are too long, bearing will be predominately axillary, and may lead to crutch paralysis, or slow atrophy of the arm. Occasionally, one is called upon to take care of a patient who has had multiple amputation. When both an upper and a lower extremity are amputated, the question of walking with crutches necessitates some adaptation to the crutch, in order to enable the patient to walk with crutches (Fig. 57).

Summary of Physical Therapy

In every case a person who has undergone amputation is a potential physical therapy patient. In the majority of cases, physical therapy should start within a few days following the amputation. In infected cases or guillotine amputations a portion of the physical therapy measures must be delayed until healing of the stump is secured, but even then a certain amount of physical therapy is indicated. The chief physical therapy measures indicated are massage, motion, hardening of the stump, splinting, and the supervision of the wearing of the prosthesis.

Massage.—Light stroking massage should be started on the stump just above the protective dressing and continued up the limb, growing more forceful and stimulating as the upper limits of the extremity are reached. As soon as the incision is healed, light stroking and kneading massage should be started over the end of the stump. The purpose is to relieve sensitiveness and accustom the patient to the touching and handling of the stump (a most important psychologic effect); to prevent adhesions and keep the end of the stump pliable; and, finally, to prepare the stump for end or partial end bearing. This massage

should be continued even after discharge from the hospital in cases of adherent scar, contractures, and impaired function in adjacent joints (Fig. 58).

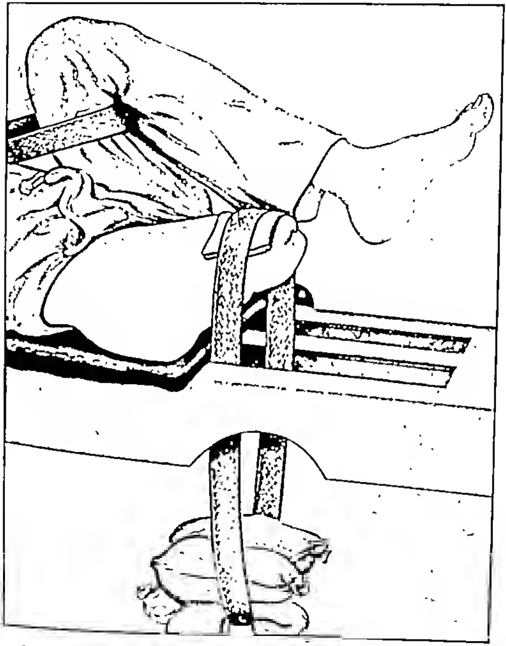

FIG. 58.—Special massage table for treatment of flexion deformity in thigh stumps. The pelvis is fixed by a webbing strap which holds the normal thigh in flexion. The strap is secured around the patient's shoulders. Traction is made downward by sand bags which are placed in a webbing strap which encircles the end of the flexed stump while the tense soft parts about the groin are massaged. (Army Med. Museum.)

Motion.—Passive and active motion of the stump and the adjacent joint should start within a few days after the amputation. At first the surgeon must gently move the joint, but within a few days the patient must be taught and stimulated to move the extremity and to flex and extend the adjacent joints several times a day. The trained technician should teach and supervise these movements following the massage.

Hardening of Stump.—Accustoming the stump to end bearing and hardening of the stump can likewise start within a few days. As soon as active motion has developed, the patient should be taught lightly to tap the end of the stump, covered by its dressing, on a pillow. Later, when the wound is healed, this tapping on a pillow is continued with

FIG. 59.—A repaired guillotine stump.

A circular guillotine operation was performed early in 1925 for the control of a chronic active osteitis of the middle third of the femur. This infection had persisted since his original gunshot injury sustained in 1918. Recurrent hemorrhage had followed an operative procedure on the femur and the foot showed evidence of circulatory disturbances. The patient was septic.

The amputation was performed through the middle of the osteomyelitic area. Dakinization and skin traction were begun at once. There were four large scars extending up the thigh, adherent to the femur, the result of former drainage incisions.

All scar tissue was removed from the stump at the time of plastic closure. The bone end was rounded off and a skin closure accomplished without bone shortening. The stump end is painless, even with direct weight bearing. The skin is not adherent to the bone end. He was fitted with an ischial-bearing prosthesis.

the stump end exposed. The hardness of the surface being tapped is gradually increased until the patient, within two or three weeks, is striking his stump rather forcibly against the bottom of a chair or the surface of a table (Fig. 59).

Splinting.—Splinting, to prevent joint contractures and faulty positions of the stump, and traction, either for the same purposes or to secure better skin covering of the stump, are likewise physical therapy measures which must not be neglected in indicated cases.

Wearing of Prostheses.—Finally, the surgeon who is rehabilitation-conscious must recognize the importance of supervising the wearing of temporary and permanent prostheses until the patient has regained the greatest possible functional restoration in the handicapped extremity.

CHAPTER FOURTEEN

PHYSICAL THERAPY IN RELATION TO THE SURGICAL TREATMENT OF ARTHRITIS

Beveridge H. Moore, M.D.

Introduction

Definition.—In discussing this subject it is well to define clearly the ground to be covered. It is not the intention to discuss the physical therapy of arthritis; that is taken care of in another chapter. This one is concerned only with the surgical treatment of arthritis in its relation to physical therapeutic measures. There is a dearth of literature on this subject. Most of the available articles describe minutely the details of the operative procedure and then blandly remark that physical therapy is a valuable adjunct in the after-care, leaving the reader to form his own conclusions as to how or why. Another point that should be cleared up preliminary to a discussion of the subject is a definition of arthritis. The classification of arthritis is at present in a deplorably muddled state. There is confusion as to the nomenclature of the various types, and to make matters worse, some authors are including pyogenic, tuberculous, and gonorrheal joints in the class of arthritis. These conditions undonbtedly are inflammations of the joints, but to include them under arthritis is to add an unwarranted burden to an already overburdened classification. What the field of arthritis needs is narrowing rather than broadening. For the purpose of this chapter, then, arthritis will be considered as an affection of the joints in which there is no demonstrable infection present in them, though they are the site of pathologic changes. That is, it is the chronic nonsuppurative arthritis which is being considered in this chapter. This will include the classes usually called hypertrophic osteo-arthritis, and atrophic or rheumatoid arthritis.

Indications for Surgery

Another point which I wish to bring out clearly is that I am by no means advocating operative surgery on all cases of arthritis, even in the limited field which I have defined. I wish to make this as emphatic as possible. There are cases of chronic arthritis which can be benefited by operative surgery, but they represent a relatively small proportion of the total number. As a general rule operative surgery should not be considered while the condition is acute. Since arthritis during this

stage is a general disease, although its chief local manifestations are in the joints, all the measures of general medicine, including diet, and physical therapy should be given a thorough trial before operative measures are considered. As a matter of fact, the question boils down to this: Surgery is more often useful in the treatment of the sequelae of arthritis than in the treatment of arthritis itself.

I would give, then, as the two principal indications for surgery in arthritis: first, the relief of pain; and second, the correction of deformities resulting from arthritis which are causing disability. These two indications, of course, will overlap to a certain extent, and in any individual case both may be present in varying proportions. It is quite logical to believe that a joint deformed by arthritis will be more subject to pain simply because it is at a mechanical disadvantage in meeting the strains for which the normal joint is perfectly adapted.

With regard to the first indication, the relief of pain, there is nothing that calls for more delicate judgment on the part of the surgeon. Much depends in this case on the personal equation of the patient. There is no standard by which pain can be measured by another person than the one enduring it. What one person may regard as excruciating agony will be regarded as discomfort by another, though so far as the physician can determine, the two may be pathologically exactly alike.

With regard to the second indication for surgery, the relief of the deformity with resulting disability, there is not quite the same indefiniteness. It is obvious that a deformed joint, for example, a knee flexed 45°, is not as useful for weight-bearing as one that is in normal position. Hence, if we can place this joint in a position which will be mechanically better, we have benefited it.

Relief of Pain

The operation most commonly used for the relief of pain in arthritis is some form of ankylosing operation by which the bones forming the offending joint are fused together. It is based on the theory that no joint at all is better than a painful one—a point of view with which many patients who are suffering are quite willing to agree. The regions in which fusion operations are of particular value are, first, the sacro-iliac; second, the spine; third, the hips; fourth, the shoulder.

ARTHRODESIS OF SACRO-ILIAC JOINTS

The sacro-iliac joints are small but exceedingly troublesome when affected by arthritis. In a recent questionnaire by the Clinical Orthopedic Society with regard to the question of the cause for low back pain, it was the almost unanimous opinion that arthritis of the sacro-iliac joint was the most common cause. The frequency with which arthritic changes are noted in x-rays of the sacro-iliac region bears

this out. It has been frequently noted that in such cases the pain has disappeared when the sacro-iliac joints have become completely fused by the pathologic process. This furnishes the rationale for fusing them by operative means—that is, it is a matter of assisting nature to do in a comparatively short time what she will eventually do herself, thus shortening the patient's period of disability. Numerous methods of fusing these joints have been devised by Smith-Peterson, Campbell, Gaenslen, Chandler, Verall, and others.

Operation.—The operations are all of two types: one in which the joint itself is cleaned out and fused, and the other in which the joint itself is not touched but is completely immobilized by building a bridge of bone across the joint, i.e., an extra-articular fusion.

In the Smith-Peterson operation, which is one of the first type, a *square of bone is cut from the ilium directly over the sacro-iliac joint,* which is curetted out through the opening and the square of bone is replaced. Gaenslen reaches the joint by cutting through a portion of the posterior wing of the ilium, turning it back, and curetting out the joint. Campbell's and Chandler's operations are very similar and are of the second type. Both do an extra-articular fusion of the sacrum and ilium by stripping away the periosteum from a portion of the sacrum and ilium and then building a bridge of the bone chips removed from the ilium across the sacro-iliac joint, causing an extra-articular fusion with resulting immobilization of the joint. Verall places a graft from the tibia across the posterior portion of the sacrum and ilium. All these methods have the same object in view, that is, the prevention of motion in the sacro-iliac joint. In one type this is obtained by destruction of the joint with a resulting fusion; in the other type, by a fusion between the sacrum and the ilium.

After-Treatment.—The primary object of the operation must be kept firmly in mind—that is, a bony union between two surfaces. In order to obtain this the involved bones must be held immobile until union has formed. It must also be remembered that it takes somewhat longer to obtain a fusion where a joint has been removed than where a fracture has occurred in a bone. How this immobilization is to be accomplished is largely a matter of taste with the surgeon. In the first stage it will be obtained by rest in bed with the patient lying on the abdomen, at least for the first two weeks. This stage of rest in bed will last from four to six weeks. Following this, sufficient immobilization can be obtained by a plaster cast. The sacro-iliac joint is not an easy one to immobilize and so the plaster must be applied skillfully to be effective. This stage will last from six to eight weeks, when the fusion should be strong enough to allow the patient to be about with a well-fitting belt for support.

Physical Therapy.—Again the primary object of the operation must be borne in mind. Any manipulation which would tend to move

the affected joint is taboo, especially during the early stages. However, local heat is often agreeable and by causing local hyperemia it may hasten the process of consolidation. Massage of the muscles of the thighs, legs, back, and arms is of benefit, in that it tends to keep these muscles in good condition and thereby shortens the period of convalescence after the fusion is firm enough to permit weight-bearing while still supported.

ARTHRODESIS OF SPINE

The theory underlying the use of spinal fusion for arthritis is, of course, the same as with the sacro-iliac joint, that is, no joint is better than a painful one. The operation is especially applicable to osteo-arthritis of the spine, in which the process is fairly well limited to one region. The cases in which the radiograph shows large crescentic lipping extending from the border of one vertebral body to the adjacent one are especially favorable. As to the technic of the operation, it is not necessary to go into the details since it has been described so many times in the literature of more recent years. It is sufficient to say there are two main types of operations for spinal fusion, the Hibbs and the Albee. In the Hibbs operation no extraneous bone is used, while in the Albee type operation a bone graft removed from another part of the body is applied to the spine to cause fusion. Each operation has advantages and the choice must be made by each individual surgeon. Either type will give satisfactory results in the hands of a competent operator.

After-Treatment.—After-treatment does not differ materially from that of sacro-iliac fusion, consisting of rest in bed, support by plaster cast, and then braces. The spine is somewhat easier to immobilize by plaster than is the sacro-iliac joint, and it seems that weight-bearing when the spine is well supported by a plaster cast which fits well tends to give earlier and more solid fusion.

ARTHRODESIS OF HIP JOINT

Fusion of the hip joint has not a wide range of application. It is limited to those cases in which only one hip is affected and affected badly. The usual type of this case is that of osteo-arthritis in which the head is badly mushroomed and deformed by the pathologic process. There are two methods of obtaining a fusion of the hip joint, the intracapsular and the extracapsular. In the intracapsular method the hip joint is opened and the head exposed and denuded of cartilage. The cartilage of the acetabulum is also removed, thus bringing raw bone in contact with raw bone. The operation is not an easy one, in fact, it is a very difficult one. Furthermore, while the placing of raw bone against raw bone should theoretically produce union, it does not always do so, and the hip joint is notoriously a

hard one to fuse. However, Magnuson states that he has had several cases in which, although fusion was not obtained by this method, there was great relief from the pain.

After-Treatment.—In obtaining fusion of the hip the after-treatment is governed by the same principles as those which apply to the spine. Immobilization should last for a period of three to four months, with weight-bearing while immobilized after four to six weeks. In obtaining immobilization of the hip a plaster cast is the most effective agent. The choice of position for ankylosing a hip joint is very important. The position usually chosen is full extension of about 15° and neither internal nor external rotation. This position is undoubtedly the best for walking or standing but is not so convenient for sitting. In order to sit comfortably with a stiff hip in the fully extended position, the patient must develop compensatory motion of the lumbar spine. Therefore, before recommending a fusion for an arthritic hip, it is important to assure one's self that there is no arthritis in the lumbar spine. No form of traction should be used after an operation to secure fusion of the hip. This is obvious, since in order to secure fusion the bony surfaces must be forced together, whereas traction draws them apart. It should be borne in mind that after a successful fusion operation, the muscles which ordinarily act on the joint tend to atrophy rapidly, since the fusion has robbed them of their function. This is the converse of the operation in infantile paralysis where the fusion is done to stabilize a joint which cannot function properly on account of a loss of power in its muscles. Massage will tend to delay this muscular atrophy but will not prevent it, since it is a result of a loss of function. However, in the three joints discussed, the sacroiliac, spine, and hips, the atrophy of the muscles is not of the consequence that it is in other regions of the body.

ARTHRODESIS OF SUBASTRAGALAR, ASTRAGALOSCAPHOID, AND CALCANEOCUBOID JOINT

Another joint in which arthrodesis may be considered as a treatment for arthritis is the subastragalar, astragaloscaphoid, and calcaneocuboid joints considered together. The special indication for fusion in this region is that type of arthritis not infrequently seen following a fracture of the os calcis. The arthritis of the subastragalar joint causes persistent pain and disability. Subastragalar arthrodesis similar to that for stabilization of a paralytic foot gives excellent results in these cases. The technic consists in clearing out the tissues from the sinus tarsi to give access to the astragaloscaphoid, calcaneoscaphoid, and calcaneocuboid joints. The cartilage and a portion of the bone are then removed from each of these joints. It is possible by a little care to remodel the bones so that the weight-bearing can be much improved.

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popliteal space from the side. This gives rather free access to the posterior portion of the capsule without great danger to the popliteal vessels and nerves. The capsule is then either divided or stripped from its attachment to the posterior surface of the femur.

After-Treatment.—In the after-care of these cases it is very important to remember that if the contracture is of long standing, not only are the tendons and capsule contracted, but also, to some extent at least, the large nerves and the popliteal vessels are tight. To attempt to stretch them violently may result in disaster—either shutting off the circulation of the leg or tearing the popliteal nerve trunks. Therefore, it is better to use some apparatus for gradual stretching. The simplest is a circular plaster cast applied from the groin to the ankle, with the knee in flexion. Before it hardens completely a circular cut is made behind the knee, leaving about two inches of plaster intact over the patella to act as a hinge. Then in two or three days this is opened by extending the knee and placing thin strips of wood in the cut to hold it open. These are added to each day and the extension is thereby increased until the full amount is obtained. Other more elaborate devices have been invented, but this method is the simplest and is effective. After the full amount of extension has been obtained, the knee should be retained in that position for about six weeks longer in order to prevent contractures from recurring.

Physical Therapy.—The next step is beginning to secure motion by passive movement, massage, and heat. These are great aids at this stage. The passive movements must be gently and slowly done, going to the point where the movement begins to be checked, then very gently a little beyond that and holding the stretch obtained for a few seconds. These movements occupy but a very small portion of the day and it is to be remembered that contractions may recur during the rest of the day. Some form of removable splint to retain the position should be worn continuously. The stretching and massage should be kept up for several weeks, until the motion present is smooth and entirely painless, though probably not the normal range of the joint. Then function should be very gently begun. First should be supported weight-bearing, then walking with the aid of crutches. The natural function of the joint is the greatest aid to improvement from this point. This is a very tedious process and by no means all patients will show improvement commensurate with the time and difficulty involved, but some will be benefited enough to be freed from a wheelchair existence, which is no bed of roses.

REMOVAL OF EXOSTOSES

Another operative measure for the relief of deformity that may be necessary is removal of exostoses resulting from arthritis. This, of

After-Treatment.—Following the operation the bones are retained in close apposition by plaster, and early weight-bearing—that is, as soon as it can comfortably be done—is encouraged while the foot is supported by the cast. From 8 to 12 weeks usually suffice to give a firm ankylosis. Following this, massage with passive and active motions should quickly restore function to the ankle joint. The manipulation around the ankle joint should be limited to dorsiflexion and plantar flexion. The reason is that these motions are a function of the tibio-astragalar joint whereas lateral motion takes place chiefly in the joints we are attempting to ankylose. Hence, no attempt should be made to secure lateral motions by manipulations.

Relief of Deformities

The relief of pain is usually the prime interest of an arthritic patient in consulting a medical man. Next to that is the relief from deformities. Oftentimes the two are associated. Again, surgery is not to be indiscriminately advised, and the degree of relief that may be promised should be accurately weighed against the suffering and possible danger that must be gone through in obtaining it. Yet sometimes (but not so often as one could wish) something may be done even in apparently hopeless cases to mitigate the difficulty of their position. A case at Cook County Hospital comes to mind, in which a young woman with the rheumatoid type of arthritis had been bedridden for years with practically every joint of her body stiffened. A bilateral arthroplasty of the jaw which turned out successfully gave her a change from a continuous liquid diet to real food, a change which gave her at least one new interest in life, even though it did not change the condition of her other joints.

FLEXION DEFORMITY OF KNEES

Flexion deformity of the knees is one of the commonest deformities resulting from arthritis which may require surgical interference. This is particularly true in cases of the rheumatoid type. When the knees are flexed to a right angle or less, certain difficulties arise which often render open operation necessary. In these cases the knees may be flexed to a right angle and there may be a few degrees of motion in the joint to either side of this angle. The examination gives the impression that the contractures are in the hamstring tendons. They often are contracted, but usually the posterior capsule of the knee joint is also involved, so that a simple tenotomy of the hamstring tendons fails to give the relief desired. The posterior capsule of the knee should be divided as well. This is accomplished most easily by an incision on the outer side of the femur, just back of the lower portion of the iliotibial band. The posterior leaf of this band can be followed to the lower end of the femur and entrance made into the

fixed, walking with the cast should be begun. When this can be easily done, a removable abduction splint may be substituted for the cast, massage and active and passive motion without weight-bearing may be begun, and the support may be gradually left off. This operation means a shorter period of disability than is necessary following an arthrodesis.

As mentioned previously, another field of usefulness for this type of operation is in the metacarpophalangeal joints. The type of arthritis in which it is particularly applicable is the atrophic or rheumatoid rather than the hypertrophic. The operation is, in effect, a type of arthroplasty. The distal end of the metacarpal bones is removed and the end of the shaft remaining is rounded off. Since this is an operation intended to increase the range of motion as well as to relieve deformity, the bony surfaces should be kept well apart during the after-care. This is best accomplished by the use of a banjo splint with elastic traction furnished by rubber bands to each finger. As soon as healing is well under way, that is, in from 10 to 14 days, gentle passive movement should be begun to be followed by active motion as soon as possible. While not engaged in motion, the finger should be kept in traction. It has been my pleasure to see cases done by Dr. Leventhal at Cook County Hospital in which there was excellent, painless motion of the fingers following this operation. The restoration of useful motion to the fingers would be quite a boon even though other joints were so badly affected that nothing could be done for them.

Synovectomy

Synovectomy or the removal of the synovial lining of the arthritic joint is an operation of value in occasional cases. It is useful in those cases in which the pathologic changes are confined to the synovial membrane and the bone and cartilage do not as yet show pathologic changes. These cases are characterized by a thickened boggy condition of the joint capsule. This must be distinguished carefully from an effusion into the joint. The basis on which synovectomy seems to give relief is apparently twofold. In the first place, an irritated sore portion of the joint is removed which is of direct benefit. In the second place, joints of this type, namely, those with thickened, boggy, synovial membrane, may be themselves foci of infection almost as much as infected tonsils. Hence, the removal of a mass of low-grade infected tissue may give considerable general relief. This operation was first advocated by Volkmann for tuberculosis of the knee. The knee is by far the most available joint for the operation of synovectomy. The joint is opened from the inner side of the patella and the synovial membrane dissected away, leaving the joint capsule intact. It should be removed completely from the suprapatellar pouch and the internal and external walls of the joint. The membrane in the posterior pouch will be left.

course, is particularly true of the hypertrophic type, since it is this form which produces exostoses. Many of these exostoses are in situations where they do little or no harm, but occasionally they may definitely limit the motion of a joint. If they are in a situation where there is weight-bearing or pressure, they may cause pain. An exostosis on the inner side of the head of the first metatarsal bone is a rather common example of the latter. If it is large enough to pinch the soft tissues between it and the head of the second metatarsal when shoes are worn, a great deal of pain is produced. Another similar example is the subcalcaneal spur, which is not necessarily the result of gonorrhea but often occurs in other types of arthritis. Removal of these spurs does not entail any great technical difficulty and does give much relief. It must be borne in mind that it has no effect whatever on the pathologic process in the joint itself. It is also wise to tell the patient that the exostoses may recur, for such recurrences are not uncommon. As to the physical therapy employed afterward, contrast baths and massage begun as soon as the skin incision is thoroughly healed have proved most efficacious. Carefully graduated early use is indicated, but it must be well controlled.

REMOVAL OF ENDS OF BONES

In the class of operations for the relief of deformity may be included the removal of the ends of the offending bones. This has a very limited range of usefulness, being practically limited to the hip joint, where only one is involved, and to the metacarpophalangeal joints. In the hip this operation may be regarded as an alternative to the arthrodesis of the hip previously described. Its advantage over the arthrodesis is that a movable hip joint results, which is more convenient for sitting but not quite so good for standing or walking. If the head and neck of the femur are removed, leaving what may be described as a "broomstick" femur, there is sure to be a very marked limp resembling that of a unilateral congenital dislocation of the hip. The limp is produced in the same way, that is, there is lacking the solid point of counterpressure furnished by the head of the femur against the root of the acetabulum. The limp may be diminished by using the Whitman reconstruction operation, as done for ununited fracture of the femoral neck. In this operation the head of the femur is removed and the greater trochanter cut off at its base. The femur is then abducted sharply and the stump of the neck placed in the acetabular cavity. The amputated trochanter will thus be moved downward along the shaft of the femur below its original position where it is fastened to the shaft. A plaster cast must be applied to hold the femur abducted until the trochanter has united in its new position. The trochanter's being displaced gives the leverage by which the muscles attached to it act to fix the pelvis during walking. After about six weeks, when the transplanted trochanter should be firmly

six weeks to three months. Personally I much prefer to reduce the deformity in this type of joint by gradual reduction by the wedging plaster mentioned previously.

There is another type of joint which gives much better results by manipulative methods. This is the type of joint in which the arthritis is of moderate grade with not much deformity, a little capsular thickening but no effusion in the joint. In fact, the joint gives the impression of a "dry" joint. Motion is often limited and is painful. The x-ray frequently shows very little change from normal. It is the type often called traumatic arthritis, from its frequent association with trauma. A typical example is the painful shoulder joint often appearing after a fall in which the weight comes on the outstretched hand. In this type of arthritis manipulation under an anesthetic often gives surprising increase in function. In manipulating these joints much care must be taken. The joint should be put through its full range of motion gently and only once. Frequently a grating or snapping will be felt which has given rise to the idea that adhesions are being broken, though it is very unlikely that there are actually adhesions between the two surfaces of the joint.

After-Treatment.—We must remember that with this type of joint we are not usually aiming so much at the correction of deformity as at an increase of function. For this reason the after-treatment will be totally different. The shoulder joint should be supported in an improved position, preferably by a splint. Each day the joint should be put through its range of motion.

Physical Therapy.—I have spoken of this type of joint as a "dry" joint. The physical therapy should be directed towards stimulating the flow of blood to the joint to aid in overcoming this dry condition. Heat is the most effective way of producing this. Personally I prefer wet heat, though the dry heat is more easily applied. In applying wet heat the dressings must be voluminous. The wet application should be covered with rubber sheeting and the hot-water bag should be applied over this to keep the dressing hot. The use of an ordinary electric pad with hot wet dressings is unsafe, though there are now electric pads specially devised for this use. The skin should be guarded against maceration, and hot dry cloths should be applied after the removal of the wet dressing to prevent chilling of the part. Massage is useful in these cases. Again the object of the treatment should be kept in mind. This indicates stimulating massage rather than sedative. The massage should be deep in order effectively to increase the flow of fluid to the joint. But the most important part of the physical therapy is the active motion of the affected joint. Nothing stimulates a dry joint so well as its natural function. This must be carefully guarded in the beginning but should be kept up to the limit of tolerance. It is with this type of "dry" joint that the so-called bonesetters have their remarkable results.

After-Treatment.—After the operation no immobilization other than that supplied by the usual dressing should be used, since it is desired to obtain motion. The quicker motion can be obtained, the better. Hence, gentle active and passive motion should be begun as early as two or three days after the operation, but it must be gently done. Heat applied to the joint hastens absorption of exudate following the operation. Function of the joint should be resumed as soon as possible, though time will vary with individual cases. Key has found that after the removal of the normal synovial membrane from a rabbit joint it is reproduced in about 60 days. This, of course, was the case with the normal membrane, which may act differently from the diseased, but at any rate it is possible for the synovial membrane to be reproduced intact.[1,2]

Manipulative Surgery

Another type of surgery sometimes used in cases of arthritis is manipulative surgery. This has a field of usefulness but it has also its dangers. As a matter of fact, in genuine arthritis, particularly of the atrophic type, it has almost no field. In this type of arthritis the deformities are caused by contraction (associated with thickening) of the joint capsule and to a certain extent of the tendons and muscles about the joint. There is also associated with this a marked thinning of the bones shown by a loss of their mineral content. If, then, we undertake to manipulate such a joint under an anesthetic, we are confronted with several dangers. One is the danger of producing a fracture, either a transverse fracture of one of the bones forming the joint, or a crushing fracture of the joint surfaces of the bones. Atrophied bone crushes with very slight pressure almost as easily as ordinary pasteboard, and will often do so more easily than the contracted capsule or tendons will stretch. Another danger is injury to blood vessels or nerves. For instance, if a knee has been flexed for years to a right angle or less, the arteries and nerves are likely to have undergone adapted shortening, and violent stretching will either rupture them or narrow the lumen so as to interfere seriously with the blood supply. For these reasons in a joint of this type the temptation to try forcible correction under an anesthetic should be resisted. If it is done, it must be done gently. The force must be applied gradually so as to permit slow stretching of the contracted tissues, and excessive force must not be used. To define excessive force in terms of pounds is quite impossible. Furthermore, it must be remembered that all bones and joints are types of levers, and the force that one applies to a bone may be multiplied many times by the lever action. Each joint must be a law unto itself. In attempting to reduce the deformity of a stiff joint by manipulation it is to be remembered that the deformity is extremely prone to recur. Hence it should be placed in a plaster cast and held in the corrected position until there is no tendency to relapse. This will be a long time, from

six weeks to three months. Personally I much prefer to reduce the deformity in this type of joint by gradual reduction by the wedging plaster mentioned previously.

There is another type of joint which gives much better results by manipulative methods. This is the type of joint in which the arthritis is of moderate grade with not much deformity, a little capsular thickening but no effusion in the joint. In fact, the joint gives the impression of a "dry" joint. Motion is often limited and is painful. The x-ray frequently shows very little change from normal. It is the type often called traumatic arthritis, from its frequent association with trauma. A typical example is the painful shoulder joint often appearing after a fall in which the weight comes on the outstretched hand. In this type of arthritis manipulation under an anesthetic often gives surprising increase in function. In manipulating these joints much care must be taken. The joint should be put through its full range of motion gently and only once. Frequently a grating or snapping will be felt which has given rise to the idea that adhesions are being broken, though it is very unlikely that there are actually adhesions between the two surfaces of the joint.

After-Treatment.—We must remember that with this type of joint we are not usually aiming so much at the correction of deformity as at an increase of function. For this reason the after-treatment will be totally different. The shoulder joint should be supported in an improved position, preferably by a splint. Each day the joint should be put through its range of motion.

Physical Therapy.—I have spoken of this type of joint as a "dry" joint. The physical therapy should be directed towards stimulating the flow of blood to the joint to aid in overcoming this dry condition. Heat is the most effective way of producing this. Personally I prefer wet heat, though the dry heat is more easily applied. In applying wet heat the dressings must be voluminous. The wet application should be covered with rubber sheeting and the hot-water bag should be applied over this to keep the dressing hot. The use of an ordinary electric pad with hot wet dressings is unsafe, though there are now electric pads specially devised for this use. The skin should be guarded against maceration, and hot dry cloths should be applied after the removal of the wet dressing to prevent chilling of the part. Massage is useful in these cases. Again the object of the treatment should be kept in mind. This indicates stimulating massage rather than sedative. The massage should be deep in order effectively to increase the flow of fluid to the joint. But the most important part of the physical therapy is the active motion of the affected joint. Nothing stimulates a dry joint so well as its natural function. This must be carefully guarded in the beginning but should be kept up to the limit of tolerance. It is with this type of "dry" joint that the so-called bonesetters have their remarkable results.

Preventive Surgery

There is still another resource which is available in the surgical treatment of arthritis. It lies somewhere between active surgery and physical therapy. It may be called preventive surgery. I have said previously that active surgery is rarely, if ever, indicated in the active stage of arthritis. Yet it is in precisely that stage that most can be done to prevent the troublesome deformities which may later require active surgical intervention.

Immobilization.—During the acute stage of an arthritis the affected joints are very sore so that the least motion causes pain. During this stage of soreness immobilization gives most grateful relief and can be made to subserve the purpose of preventing deformities. Immobilization may be accomplished in various ways, all of which have the same object in view.

Casts.—The first is by circular casts. A cast applied to immobilize the affected joints should extend far enough above and below the joint to render immobilization complete. For example, a cast applied to the knee and extending only five or six inches above and below it is a very ineffective method of immobilization and will not give the desired relief. It should extend at least from the groin to the ankle and it is better for it to include the foot. Similarly, if the elbow is the joint affected, the cast must extend at least from the shoulder to the wrist. If it is the hip or the shoulder, the cast must include practically the entire trunk. The joint to be immobilized should be placed in the position which will produce the least inconvenience if it should remain stiff either permanently or temporarily. These positions are as follows for various joints: first, for the shoulder, abduction should be to nearly 90° with the humerus at an angle of about 45° to the lateral plane of the trunk. Second, for the elbow, there should be 90° or a little less for the right and a little more than 90° for the left if the patient is right-handed. Third, the wrist should be dorsiflexed about 40°, since this position allows the fingers to flex easily. Fourth, the hip should be placed in the lateral plane of the body and abducted about 10°. With regard to the hip, this position is open to some argument. It is the best for walking or standing but it is inconvenient for sitting. A few degrees of flexion, 15° or 20°, make sitting much more comfortable and do not interfere much with walking. It is to be remembered also that the types of arthritis being considered very rarely result in complete bony ankylosis, so that some motion will frequently be developed later, which is useful if it is painless. Fifth, the knee should be immobilized in a straight line but never hyperextended. In order to prevent this the limb should be supported both at the ankle and the knee while the cast is being applied. Sixth, the ankle should be immobilized at a right angle to the tibia with the foot neither

pronated nor supinated. Inasmuch as arthritis only occasionally affects a single joint, various combinations will have to be worked out with the above principles in mind. The disadvantage of a circular cast for immobilization in acute arthritis is that it precludes the use of any of the other therapeutic agents, such as heat, etc. This may be avoided by splitting the cast on each side while it is still wet. The anterior half can then be removed for inspection of the joint or application of heat, and replaced after that treatment is finished. In this way both the benefits of the immobilization in the prevention of deformity and the physical therapy can be combined. It ought to be remembered that the actual therapy takes a comparatively short time each day and that much of its effect can be lost during the remainder of the 24 hours.

Traction.—Another form of immobilization that is useful is traction. During the acute stage of arthritis there is much spasm brought about by friction of the sore joint surfaces on each other. This muscle spasm is apparently nature's effort to immobilize the sore joint. Traction acts by drawing these sore surfaces apart and so reducing the friction in the joint. It has this advantage over the simple immobilization by casts or splints. The use of traction by adhesive plaster is so well known that it is not necessary to describe the method. However, there is one detail which is overlooked at times and which greatly diminishes the effectiveness of the method. That is that the adhesive should never be applied beyond a point four or five inches below the joint on which traction is being made. If it is placed higher than that, the traction is exerted mainly on the skin above the joint with little benefit except from the immobilization of the joint. Of course, in the discussion of prevention of deformities by immobilization by casts or traction it must be understood that this applies to those in the acute stages who are still bed patients.

Conclusion

In closing the chapter I wish to reiterate most emphatically that operative surgery is not advocated for every case of arthritis, no matter what the type or whose classification may be followed. Surgery in arthritis will always occupy a distinctly back seat (although "always" is an extremely dangerous word in medical science). Nevertheless many arthritic patients have been distinctly benefited by well-judged surgery. There is no field of surgery which calls for finer judgment, not alone of the physical condition, but of human nature. Each case must be carefully individualized, not only with regard to the patient's specific condition, but as to his general condition and his mental reactions as well. He must be willing and able to put much effort into his own after-treatment. All the other resources of medicine and physical therapy should be thoroughly tried before considering

surgery. But if surgery must be done, "more power" to the surgeon and the patient.

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CHAPTER FIFTEEN

PHYSICAL THERAPY IN THE TREATMENT OF BRAIN AND SPINAL CORD LESIONS

Loyal Davis, M.D., and John Martin, M.D.

The treatment of lesions of the brain and spinal cord should be directed toward the restoration of the patient to a normal life of social and economic independence. The physician frequently makes the error of looking with an attitude of hopelessness upon the disabilities which result from injury or disease of the central nervous system. The result of this fatalistic outlook may be a life of invalidism for the patient, with physical and financial dependence upon his relatives or community. There is no doubt but that many of the crippling deformities and contractures which commonly result from cerebral and spinal cord involvement could be partially or wholly avoided by a well-directed regime of physical therapy.

Cerebral Lesions

The paralysis which results from disease or trauma of the cerebrum is always spastic in character. Quite commonly the paralysis may at first be flaccid, with the absence of all the deep tendon reflexes, but eventually an increase of tone develops in the muscles of the affected extremities, and this change is accompanied by other signs and symptoms of an upper motor neuron lesion. Briefly these are: increased deep tendon reflexes; absent superficial reflexes; the presence of pathologic reflexes (such as the Babinski, Oppenheim, Gordon and Chaddock signs); absence of muscle atrophy; and absence of the reaction of degeneration. The motor loss which occurs as the result of a cerebral lesion is in most instances hemiplegic in nature, although spastic monoplegias and diplegias also occur. In the hemiplegic type the arm is commonly much more affected than the leg, while the face is paretic in various degrees in different cases.

The most common lesions which produce cerebral spastic paralysis are: (1) cerebral vascular accidents (hemorrhage, thrombosis, embolism); (2) intracranial space-occupying lesions (tumors, abscesses); (3) cerebral palsy or "diplegia" of childhood; (4) traumatic lesions of the brain; and (5) inflammatory diseases of the brain or its meninges (meningitis, encephalitis).

Etiology.—Vascular Lesions.—Cerebral vascular lesions rank first as the most common cause for all the hemiplegic states. Following an arterial hemorrhage or an embolus the onset of symptoms is sudden and acute. The symptoms of a thrombosis are more gradual and in-

sidious in their development. If death does not occur during the first three weeks following a cerebral hemorrhage, improvement in the paralysis uniformly appears and may be progressive for many months. Most frequently the leg will show the first signs of improvement and this is followed by the face, while the arm, being the most severely involved, is the last to show a return of function. At first the reflexes are absent or greatly depressed and the muscles are correspondingly limp and flaccid. Gradually the reflexes increase and finally become exaggerated. Rigidity and stiffness appear in the paretic extremities and foreshadow the contractures which will later develop. Such contractures are always much more severe in the upper extremity than in the lower. The flexor muscles predominate over the extensor in the arm, so that the fingers become drawn into the palm of the hand, the wrist is strongly flexed, the forearm is fixed in pronation, and the elbow is semiflexed. With all the joints thus flexed, the entire extremity is held close to the side of the chest. If the fingers, wrist and elbow are forcibly extended by the examiner and then released, they fairly snap back into their former position. If allowed to remain unchanged in these attitudes, the joints become ankylosed, muscles and tendons become rigid and contracted, and deformities result which rapidly become irreparable. Passive manipulation of such an extremity is quite painful to the patient. In the lower extremity rigidity of the muscles develops in the position of extension. The knee is extended rigidly, and there is a tendency for the foot to assume a position of equinovarus. Thus the distal segments of both the upper and lower extremities are affected to a greater degree. In the presence of marked contractures the limbs are moved as a whole by the muscles of the pelvic and shoulder girdles, with little or no motion of the individual joints of the extremities. In walking the weight is carried upon the sound leg, and by the trunk and pelvic muscles the paralyzed extremity is swung forward, the toe dragging in an arc-like course around the heel of the unaffected foot. This is the typical "circumduction" gait of the hemiplegic patient.

Evidence of circulatory disturbance may be quite marked in the paralyzed arm or leg. At first the limb appears red and cyanotic; perspiration may be profuse; the skin may become soggy and macerated. Growth changes may appear early in the hair, nails and skin. Eventually the skin temperature of the affected extremities is much lower than that of the unaffected side, so that the weakened extremities may actually feel cadaveric to the touch. While trophic changes in the early stages of a hemiplegia are not common, an acute decubitus lesion may develop any place on the affected side, especially as the result of prolonged pressure, and ulceration in the palm may occur from the severe pressure of the nails of the rigidly flexed fingers. When the muscles atrophy it is because of disuse. Electrical examination shows a normal reaction of the muscles and peripheral nerves to the faradic and galvanic currents.

The paralyzed hand may suddenly open or the spastic leg become

flexed, quite independently of any voluntary effort. Following such instinctive actions as yawning, sneezing or stretching, the entire upper extremity may be raised over the head. Or, if the patient attempts to close and open the sound hand, similar abortive movements may occur on the paralyzed side. These associated movements and certain athetoid phenomena must be evaluated properly to avoid the false assumption that they signalize the return of voluntary movement in the paralyzed limbs.

Space-Occupying Lesions.—The paralyses which develop as the result of intracranial tumors or chronic abscesses are also of the upper motor neuron type. However, if they are small enough, or well enough localized to one small functional area of the cerebral cortex, they may involve only one extremity upon a side. Moreover, the development of *the paralysis is more gradual, and quite frequently the patient is able* to trace the successive involvement of the face, arm and leg. In contradistinction to the hemiplegia caused by vascular accidents, the involved extremities rarely exhibit the initial stage of flaccidity because the onset of the paralysis is usually less acute. However, in the presence of a tumor or an abscess the muscles are ordinarily spastic and rigid from the beginning. An exception to this may be made in the uncommon event that a sudden hemorrhage occurs within a tumor mass. The resultant massive insult to the cerebrum may then be so great that a flaccid hemiplegia or monoplegia results, later becoming spastic. Convulsive seizures in the involved extremities (of localizing value), or repeated tonic spasms, are common irritative phenomena which accompany intracranial space-occupying lesions. In all other respects the paralyzed extremities exhibit the same characteristic symptoms that have been described in the more acute hemiplegic state.

The surgeon who successfully removes an intracranial tumor which has produced a hemiplegia has only partially fulfilled his obligation to the patient. Every possible means should be exhausted in the attempt to restore the use of the arm and leg by the many possibilities of physical therapy.

Cerebral Palsies of Childhood.—Spastic diplegia (also called Little's disease) is the most common form of congenital cerebral paralysis, although hemiplegias and monoplegias also occur. In the hemiplegic or quadriplegic types the arms are commonly affected more severely than the legs. More frequently than not such a condition is associated with a mental defect or with epilepsy. The severe forms are obvious at birth, but milder cases may not show definite symptoms before the age of six or seven months. Grossly the brain is usually small, and there is sclerosis and cortical atrophy on one or both sides. In Collier's words, it is a "small, primitive type of brain, destitute of neurones."[1]

In some children suffering from this condition the rigidity and spasticity are so great that the extremities present a lead-pipe resistance to passive movements of any sort. The spasticity in the lower extremities

tends to flex the hips and knees, and to adduct the thighs until the knees are held so close together that it is difficult to bathe and dress the patient. If the child is placed in a chair, the rigid lower limbs remain unsupported in a horizontal position. When the patient is placed upon his feet, the legs cross, the heels fail to touch the floor, and walking is impossible. As the child grows older there is a tendency for the development of an equinovalgus or equinovarus as well as a genu valgum. Some patients manage to keep the feet widely separated so that a shuffling gait, with toes scraping along the floor, is accomplished. In the milder forms of the disease the patients exhibit only slight spasticity of the legs, so that there is only a tendency to walk on the toes.

Many such children develop involuntary athetoid or choreoid movements in the hand, usually from nine months to two years after the onset of symptoms. Such movements become very complex and may be intensified and accompanied by involuntary grimacing upon voluntary attempts to move the limb. When the patient tries to grasp an object, the fingers are hyperextended and widely separated. The hand approaches the object in a clumsy, slow, awkward, and poorly controlled manner. These movements may even become so serpentine that the patient's arm winds about his neck or back. In the majority of cases these vigorous involuntary movements appear only when stimulated by voluntary effort or by some emotional disturbance, and though they are purposeless they are useful in keeping the muscles in a good state of nutrition. Associated movements which occur when the paralyzed extremity attempts to follow the healthy limb are more marked and bizarre in these cases than in the hemiplegias which have been described previously.

Contractures in the extremities develop rapidly, just as in the spastic paralysis due to vascular lesions, so that grotesque attitudes may result. The low mentality of the patients, and such complicating factors as blindness and epilepsy seriously influence the treatment, since therapy must be directed toward the mental state by special tutoring until such a time as the brain can be assumed to have attained its full and definitive development.

Trauma.—The commonest forms of trauma to the cerebrum are gunshot wounds and depressed or comminuted fractures of the skull. The former constitutes a common lesion in time of war, while the latter is frequent in civilian life following automobile accidents. Such injuries, involving the motor cortex, cause a spastic paralysis that is usually hemiplegic or monoplegic in form, and indeed the injury may be so discrete in the brain as to cause quite an isolated paralysis of some part of the body. Recovery from the initial cerebral damage in this group of cases offers a good opportunity for the active treatment of these patients by physical therapeutic means. Here, again, the paralysis is of the upper motor neuron type, with spasticity of the involved extremities and increased deep tendon reflexes similar to those seen in the lesions previously described. Failure to institute adequate treat-

ment results in the development of contractures and ankylosed joints which deform the extremity beyond hope of returning the individual to a useful position in life. Other injuries occurring at the same time as the cerebral trauma may require prolonged hospitalization, such as a fracture, or an osteomyelitis from a badly soiled compounded fracture, and contractures may even develop while such complications are being taken care of if physical therapy is not instituted at the proper time in the handling of the paretic extremities.

The disabilities arising from these lesions are due to direct injury of the brain or occur as the result of subsequent infection. Early and thorough surgical treatment of these wounds with adequate débridement and primary closure affords the best method of securing rapid healing with a minimum of eventual motor loss. Of recent years the derivatives of sulfanilamide have been of great aid in controlling the infections which tend to develop in such wounds. The residual loss of function in traumatic lesions of the brain depends, of course, upon the exact site of the injury. It is not uncommon to observe complete paralysis of the upper and lower extremities as the result of an injury to the frontal or occipital lobes some distance from the motor cortex. One patient, J.A., was struck by an automobile and sustained a comminuted skull fracture over the posterior parietal area, and when the wound was surgically cared for 35 or 40 grams of cerebral tissue, macerated and mixed with hair and street dirt, were removed from the wound, along with fragments of bone. The cortical injury was well posterior to the sensory area of the right cerebral hemisphere, yet the man suffered a paresis of the left side of the face and left upper extremity with only slight loss of position sense in that limb. He later developed typical jacksonian seizures involving the left side of the face and the left arm. In such instances, however, unless there has been actual injury to the precentral area of the cortex, one may expect with some confidence to see a gradual disappearance of the paralytic symptoms. Immediate and severe paralysis, which is more commonly hemiplegic in character, results from direct injury to the motor cortex. At first this paralysis is flaccid with abolition of all reflexes. Soon, however, there is an increase of tone such as has already been described in the hemiplegic state. The deep tendon reflexes become increased, well-marked spasticity develops, and, if active treatment is not instituted, contractures and malpostures appear.

Inflammatory Lesions.—When either an acute or low grade inflammatory process becomes established in the meninges and subarachnoidal spaces of the brain there may result a spastic paralysis which differs in no way from that described following other cerebral lesions. While immediate recovery from meningitis is now less problematical than it formerly was, due to the use of sulfanilamide and its derivatives, it is not at all uncommon to see paralytic sequelae follow recovery. This is also true of encephalitis. The paralytic complications of both of these inflammatory lesions are more common in children than

they are in adults. They are both accompanied frequently by convulsive seizures which are commonly jacksonian in type. These latter may be so frequent that a true status epilepticus develops. It is interesting to note that in these cases the cortical tissue may become very sclerotic, hard and firm, so that a ventricular needle is introduced with some difficulty and with the sensation of passing it through hard, sandy soil.

Clinically, the children who have suffered from encephalitis and then develop spastic paralysis are much like those children who have had spastic palsy from birth. While the paralysis in the latter instance is more commonly due to hemorrhages (frequently of a widespread, interstitial type) which occur during birth, the former paralysis may develop as the result of an infection at any time. In contrast, also, their mentalities may be quite normal. The spasticity of their extremities and the deforming contractures of their hands and feet are similar in all respects.

TREATMENT OF LESIONS RESULTING IN MOTOR DYSFUNCTION

The widespread feeling that recovery from the paralysis of a cerebral lesion was impossible has been responsible, to a great extent, for the lack of concerted effort toward the continued treatment of these patients. In 1915 Franz, Scheetz and Wilson [2] called attention to the fact that the conclusions regarding the permanency of paralysis from cerebral accidents were neither accurate nor based upon scientific principles. They pointed out the striking improvement which could be effected by careful and persistent attention to this group of cases.

In general, the treatment of the paralysis resulting from cerebral lesions may be divided into that which is used immediately and that which may be employed later in the course of the lesions.

There is little donbt that complete mental and physical rest for a prolonged period is one of the most important steps in the treatment of cerebral damage, regardless of its etiology. By rigid enforcement of this treatment, the cerebrum may be given every opportunity to recover its normal function as much as possible. Particularly in vascular accidents such a method of treatment will aid in preventing what may be a fatal recurrence. Good nursing, with careful attention to the skin of the back and buttocks, will prevent the development of decubitus sores which may be very difficult to heal and may impede the application of physical therapy. Attention to the bladder, which may distend and overflow, will often prevent the extreme restlessness exhibited in traumatic cerebral cases. The patient's position must be changed frequently, particularly the aged, if the development of "wet lungs" or frank pneumonia is to be avoided. Dehydrating agents, such as 50 per cent sucrose administered intravenously, should be used judiciously in the acute phase of trauma or cerebral vascular accidents, as well as after the surgical removal of certain tumors, in the effort to keep brain swelling at a minimum. Spinal punctures are useful in the early stages of the treatment of traumatic lesions, and when done carefully with

manometric control they not only drain off the bloody spinal fluid which acts as an irritant and causes restlessness, but they also offer the best means possible of keeping patent the absorptive mechanism in the cerebrospinal fluid spaces, the arachnoidal villi.

Paralyzed Extremity.—The adoption of measures to insure rest should in no way interfere with the early treatment of the paralyzed extremity. Gentle massage of the muscles of the involved extremities should be instituted as early as possible after the shock of the original trauma has disappeared. This may be associated with mild faradism to provide gentle exercise of the muscles. The chief concern of the nurse should be to prevent the helpless extremities from remaining in a fixed position. Often bedclothes are allowed to rest upon a paralyzed foot so that it is forced and held in a position of footdrop. A cradle which will keep the weight of the bedclothes off the extremity and yet will allow freedom of movement of the sound limb may be made very simply. Passive movements of all the joints and in all directions should be carried out very gently and should be repeated several times each day.

Splints.—The employment of light but effective splints to correct the tendency of a segment of an extremity to assume a malposition is important. The heavy, permanent type of splints, however, may do more harm than good. For example, the use of a light crinoline posterior molded splint which is well padded will be just as effective in keeping the foot in a correct position at right angles to the leg as will a heavy cumbersome plaster-of-Paris splint. As a matter of fact, pillows and sandbags may be used in a very effective manner to prevent deformities. The important objects to be obtained are frequent changes of position and the prevention of overstretching of paralyzed muscles.

Splints are not so satisfactory in old neglected cases of spastic paralysis as they are in cases of flaccid paralysis. However, they may be employed judiciously to help overcome long-standing deformities. Temporary splints should be devised which employ elastic tension, else the harm from oversplinting may interfere seriously with their efficiency. Each splint should be constructed to meet the individual patient's need and to help him obtain the most satisfactory results. An easy way in which to procure such simple splints, adapted to the special need of the patient, is to fashion them from sheet aluminum or other malleable metal with hand metal-cutting shears. Snch splints, properly molded and padded, are quickly and inexpensively made. Here, again, however, too much tension must be avoided, since it is undesirable to excite reflex muscle contractions which would defeat the purpose of the splint.

Voluntary Movement.—As the patient begins to recover, voluntary power will return in the proximal muscles of the hemiplegic extremity, and the increased tone of the muscles will be apparent. At this time the patient's help must be sought. He should be told that the ultimate degree of recovery of function depends to a great extent upon

they are in adults. They are both accompanied frequently by convulsive seizures which are commonly jacksonian in type. These latter may be so frequent that a true status epilepticus develops. It is interesting to note that in these cases the cortical tissue may become very sclerotic, hard and firm, so that a ventricular needle is introduced with some difficulty and with the sensation of passing it through hard, sandy soil.

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It must be emphasized that the personal attention and care of a trained physical therapist can never be replaced or improved upon by any kind of mechanical device. The therapist not only exercises patience and human understanding, but is able to adapt herself and her physical agents much more to the patient's needs than can ever be expected of a machine. The ideal combination, obviously, is composed of trained hands and good mechanical equipment.

Active Movements.—Even though marked contractures are present in late neglected cases, usually active movements are possible, in some degree or other, in the affected extremity. The patient should be encouraged to practice these movements daily many times. It is often necessary to associate them with simple purposeful acts, so that the patient's interest and enthusiasm may be held. Above all, he must be completely relaxed and at ease during these periods of practice. No attempt should be made to use a spastic muscle until it is relaxed. The patient should sit erect, but at ease, beside a table of correct height. The elbow and entire forearm of the flexed extremity should rest on the table. Relaxation of the elbow, wrist, and hand is then possible. It is common to observe a hemiplegic patient perform movements which he is wholly unable to repeat upon command or in the presence of strangers, but he must not be allowed to develop a defeatist attitude, and he must be told that failure to perform his exercises properly is no cause for discouragement. The tasks to be accomplished must be increased slowly and patiently, and he must be made to believe that his recovery depends largely upon his own attitude.

The use of simple mechanical devices is perhaps the most valuable method of obtaining active exercise of muscles. This routine of muscle education should be planned to utilize and develop the intact residue to the highest degree of efficiency. Purposeful occupations and play center the patient's attention upon his accomplishments rather than upon his disability. While the spastic patient may be able to perform given exercises, it is well to show him by means of occupational therapy that such movements may be quite practical. This is most important in cerebral palsies of childhood in which, of course, the treatment is limited in extent by the mentality of the child under treatment.

While gross arm or leg movements may be accomplished rather quickly, the hands and fingers recover far more slowly and are more obstinate in their resistance to treatment. Franz and his co-workers found that one of the simplest and most effective exercises was to have the patient attempt to open the fingers after a ball was placed in the hand. An elastic rubber ball is perhaps the best such object to use. At first this act may be almost impossible, but soon the patient may be able to perform such a movement and pick up the ball as well. The time required to grasp and release a ball may be used as an accurate record of the patient's progress. Attempts to draw a straight line with a pencil; to sort colored glass beads; to arrange wooden blocks; to solve jigsaw puzzles; to use a fan (this develops pronation and supina-

his enthusiastic and persistent co-operation. He must not be allowed to lie in bed with the paralyzed arm flexed and folded across his chest. He should place it away from his body, fully extended, and with the hand supinated. As passive movements are instituted, he should be asked to attempt each individual movement with each performance and to hold the segment in the position into which it has been moved passively. The arc of the movement should be completed each time a passive movement is employed.

The patient should be closely directed from the beginning of the return of the first voluntary movement. The tendency is for him to keep repeating that particular movement to the exclusion of all others. He should be taught to attempt new movements and to persist in those attempts whether or not they are at first attended by success. It is well for him to practice simple, purposeful movements such as he would ordinarily perform in his daily duties, such as dressing himself, handling his own food at table, writing, and receiving objects of various kinds into his hands. The ability to keep him from becoming discouraged may account for success or failure, and if his movements accomplish a purpose his interest and courage will be maintained.

MASSAGE, VIBRATION, HEAT.—In spite of the most carefully directed methods of early treatment in cases of upper motor neuron paralysis, spasticity and rigidity of the muscles will tend to develop because of the inherent nature of the lesion. Consequently, more strenuous methods of treatment to prevent deforming contractures and joint ankylosis will become necessary.

Unfortunately, most patients who have received cerebral damage present themselves for treatment after spasticity and rigidity of the muscles and deforming contractures have developed. In the presence of marked spasticity, incorrectly employed massage not only may be useless but may increase the rigidity. Spastic extremities exhibit heightened reflexes. Knee and ankle clonus may be elicited by the slightest stimulus. The lightest touch to the lower extremity at any point may produce a marked withdrawal defensive reflex of the entire limb. Therefore, massage should be very light and should consist more of stroking than of rubbing. Franz was able to reduce the hypertonicity considerably by vibration. In this maneuver the hand is grasped and the arm is shaken or vibrated gently until a distinct loosening of the muscles has been noted. Dry heat before massage is begun is of distinct aid in securing this reduction of hypertonicity, but in our experience immersion of the limb in a gentle, warm, whirlpool bath has been more effective. However employed, heat improves the circulation to these extremities which are colder than the normal limb.

Because of the increased reflex activity in these limbs, electrical stimulation of the muscles in the late stages of treatment is, in general, contraindicated. If mild faradization can be used without exciting reflex movements of the muscles, it may help to provide active gentle exercise for the muscles which are inactive.

ning, the patient must be encouraged to practice assembled and coordinated exercises designed to teach him the proper way to walk. He must not be allowed to walk in the manner easiest to him (circumduction of the entire leg, without flexion of the hip or knee) without making an effort to correct it. He should not be allowed to watch his feet, in order that he may more quickly reflexly control his balance. He should be made to support his own weight and maintain his own balance as completely as possible. Rubber-soled shoes and a rubber cap on his cane will add greatly to his feeling of security.

PASSIVE MOVEMENTS.—Passive movements of all joints should be performed patiently and carefully by someone trained in such work and who has a knowledge of the anatomic parts involved. These movements may be quite painful at first and therefore must never be done in a violent manner, and force and determination cannot be used to overcome a spastic muscle. At the same time the patient must be taught to perform passive movements by himself with the aid of his sound extremity, and this he can do while sitting quietly alone without other occupation. In this manner the joints may be kept supple, so that when active attempts are made the joints can be moved.

Report of Cases.—The following brief report of two cases will serve to illustrate the problems which one encounters and the results which may be obtained in the treatment of this group of patients.

W. R. (Fig. 1), aged 40, fell off a fast-moving truck and struck his head upon the concrete pavement. There was an "egg-shell" fracture of the right parietal bone. The patient was unconscious for twelve hours. When he recovered from his coma, complete flaccid paralysis of the left arm and leg was observed. Eighteen hours later the lower half of the left side of the face was involved.

It was felt that there were no surgical indications present. The patient was treated by hypertonic solutions. The period of flaccidity remained for ten days before a gradual increase in tone was noted. During this time gentle massage of the arm and leg was given as well as passive movements of all the joints. The left foot was kept at right angles to the leg by the use of sandbags and pillows.

As spasticity developed, the arm tended to flex across the chest. This was kept abducted and extended by the use of sandbags and pillows at night. During the day passive movements were carried out in all of the joints throughout their entire range of movement. At the same time the patient was encouraged to attempt the same movement voluntarily.

The first return of voluntary movement was noted in the face after three weeks and this was followed rapidly by movements of the upper arm and then by movements of the fingers. Active movements of the leg returned last of all because the motor cortex near the vertex was contiguous to the site of the fracture. When the patient was able to be out of bed after six weeks, definite purposeful exercises were instituted for the arm and leg. Graduated exercises and persistence with determination on the part of the patient resulted in a most satisfactory return of function after a few months, so that the patient was eventually able to return to a normal life with a minimum of permanent disability.

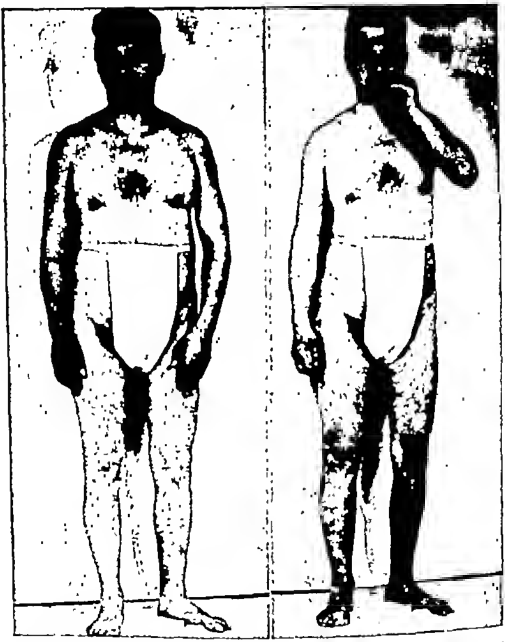

FIG. 1.—Posttraumatic hemiplegic patient after six months of intensive physical therapy. He was able to walk when discharged from the hospital seven weeks after injury, and for over six months he was treated by massage, active and passive motion, and graduated re-educational exercises. When last seen, eleven years after his accident, he was entirely well except for a slight residual spasticity in the left hand.

tion); to "climb" a small wooden ladder with the fingers; and to use a needle and thread, are several simple methods of developing smoothly coordinated movements of the upper extremity. Similar simple, active exercises may be devised to re-educate the muscles of the lower extremity. No attempts to move the lower limb should ever be made when the patient is not at ease and well balanced. From the begin-

various types of aphasia or of the anatomic location of the cerebral lesions responsible. Many simple exercises may be devised to reeducate these patients, based upon the description of the various types of aphasia given by Head.[3]

Verbal Defects.—"In severe forms of this disorder the patient's utterance may be reduced to 'yes' and 'no' and even these words cannot always be evoked or voluntarily used. As speech returns, his vocabulary increases, but his enunciation is slow and halting. Any word he is able to recall can, however, be used for naming an object. It may be so badly pronounced that it is scarcely recognizable, but it is applied correctly. When the patient attempts to repeat what has been said to him, the articulatory words are imperfect, although he can usually repeat more words than he can pronounce spontaneously. It is characteristic of this form of aphasia that words are evoked with difficulty and tend to be abnormal in structure.

"At first the comprehension of verbal significance may be somewhat impaired. But, after the stage of neural shock has passed away, the power of understanding the meaning of words is rapidly restored; these patients can not only choose an object to oral or printed commands but even complex orders may be executed correctly.

"The power of reading to themselves with enjoyment is spoilt by difficulty in remembering a series of words accurately; they are frequently compelled to look back to the beginning of a long sentence in order to obtain its full meaning. On the other hand, reading aloud is hampered by the same defects as articulatory speech.

"As the spoken vocabulary increases, the power of writing is regained, although throughout it tends to show the same errors as articulatory speech. These patients cannot spell and find difficulty in remembering the order of the letters, even in simple words. They write more easily to dictation, but are unable to carry in the memory a string of words or a long phrase. Ability to translate printed words into cursive script, though at first diminished, is as a rule rapidly recovered."

Syntactical Defects.—"This is an easy form to distinguish, because the patient tends to talk jargon. Not only is articulation of the words ill-balanced, but the rhythm of the phrase is defective, and there is want of grammatical coherence. The power of naming objects may be retained in spite of the gross defects by which speech is hampered. Not infrequently, when the patient cannot utter a name, or when the sound emitted is incomprehensible to his auditor, he writes it correctly, proving that he is familiar with the usual designation of the object.

"Comprehension of the meaning of words is always in excess of their use in conversation. These patients can choose common objects or colors without fail to oral commands in the form of a single word; if, however, the order is conveyed in a spoken phrase, it may not be

FIG. 2.—Photograph of a fibroblastic meningioma, weighing 98 grams, removed from the right frontoparietal area of the cerebral cortex in a man with a complete left hemiplegia. Following its removal, physical therapy was instituted and in less than five months the man was restored to his former occupation as manager of a shoe store.

L. W., aged 53, was operated upon and a fibroblastic meningioma (Fig. 2), weighing 98 grams, was removed from the right cerebral hemisphere. The motor cortex lay directly under the tumor, as was attested by the patient's history of epileptiform seizures and left-sided weakness. Following total removal of the tumor the patient was in every way improved except that his motor weakness was somewhat increased and with it there developed a spasticity of the muscles which appeared within a few days postoperatively. Though the patient was at first not co-operative and disliked any sort of passive manipulation, physical therapy treatments were started as soon as he could be taken to the physical therapy department of the hospital. There heat, massage, passive and active exercises were instituted with remarkable success. With continued urging the patient stopped favoring the left hand and used it for purposeful movements, gained sufficient confidence to walk with less support, using a cane, and became able to swing the left upper extremity at his side when walking with all normal associated movements. In this man's case, not only was good physical therapy needed and used, but a proper mental attitude and understanding of the problem had to be developed within the patient himself, and with each little improvement his enthusiasm mounted.

Speech Defects.—Lesions of the left cerebral hemisphere in right-handed individuals, or of the right cerebral hemisphere in left-handed individuals, may be accompanied by aphasia. This is particularly characteristic of vascular lesions and is less common in intracranial tumors or following trauma. It is unnecessary to enter into a discussion of the

ciation of meaning and inability to evoke a desired name; both internal and external speech suffer as a secondary result.

"Such patients read with extreme difficulty both to themselves and aloud, especially if they attempt to spell out the words. Single letters, even if correctly enunciated, frequently fail to convey their full nominal significance. Printed orders are badly executed; but to read them aloud is a decided aid to their correct performance.

"Both the act of writing and the power of conveying the intellectual content of ideas, evoked spontaneously or in response to something heard or read, are greatly affected. Writing to dictation shows the same calligraphic faults, although the subject matter is somewhat better reproduced, and, in the severe forms, these patients slavishly copy printed or cursive letters, but cannot consistently translate print into ordinary handwriting.

"They can usually count, but suffer from defective appreciation of the meaning of single numbers. This interferes with the power to carry out simple arithmetical operation, and capacity to formulate the relative value of two coins, or to calculate change, is usually more or less affected. Games, such as cards, which demand rapid and correct recognition of names and power to register a score, are impossible. On the other hand, chess, draughts, and dominoes may be played correctly.

"Drawing from a model, or from memory after the object has been removed from sight, is easily performed. But, when the patient is asked to draw some such figure as that of an elephant from imagination, the result is extremely unsatisfactory; all the distinctive features are usually omitted.

"He can usually find his way from place to place so long as distinctive landmarks are in sight; but he may have considerable difficulty in planning his route beforehand, or in describing the salient objects he would meet on his journey. One of the most instructive forms assumed by the loss of function in these cases is the want of ability to draw a ground plan of some familiar room. Asked 'Where is the table?' or 'Where is the window?' he can point to the situation of each correctly; but he cannot express their relative position in the abstract form of a ground plan. Moreover, he tends to slip into an attempt to express the principal pieces of furniture in elevation, evidently reproducing his concrete visual images."

Semantic Defects.—"This form of aphasia is characterized by want of recognition of the ultimate significance and intention of words and phrases, apart from their direct meaning. But other functions suffer that have no immediate bearing on verbalization; for in this form of disordered speech there is loss of power to appreciate or to formulate the general conclusion of a connected train of thought. The patient may understand a word or short phrase, and can appreciate the various details of a picture, but the significance of the whole escapes him. Thus, although he comprehends the meaning of 'summer'

understood correctly. In daily intercourse they suffer from inability to recall with certainty what they have been told; not only is phrasal utterance defective, but phrasal memory is transitory. This makes consecutive conversation difficult or impossible, and leads to an apparent slowness of apprehension.

"Such patients can understand what they read to themselves, provided they are not compelled to reproduce the meaning in words, either silently or aloud; for their internal speech is also disturbed by jargon.

"Single words may be written correctly, but any attempt to convey a formulated statement in writing is liable to end in confusion. Patients suffering from the more severe degrees of this affection cannot write a letter; but in slighter cases writing is easier than articulatory speech, and all of them can copy correctly, transcribing print into cursive handwriting.

"Counting and the use of numbers is not materially affected, except that the pronunciation of the actual numerals is liable to be defective. There is no difficulty with the manipulation of money, or in giving the names and relative value of coins.

"These patients can understand the full meaning of pictures, but they are greatly hampered by their jargon, if they attempt to convey to others or silently to themselves what they have gathered. They are able to draw, unless misled by defective verbalization, and can often produce an accurate ground plan of some familiar room.

"This disorder is essentially one of balance and rhythm in symbolic expression, and syntax suffers greatly. The patient has plenty of words, but their production is ataxic, and they are strung together without the usual connecting links. This leads to jargon and renders difficult even internal formulation of words and their meaning."

Nominal Defects.—"This is essentially a loss of power to use names and want of comprehension of the nominal value or meaning of words and other symbols. Not only does the patient fail to name objects placed in front of him, but, when asked to point to one of them named aloud or in print, the choice, even if correct, is made slowly and with effort.

"There is no lack of words and, if the patient is intelligent, he evokes one after another, all more or less aptly associated with the name or expression he is trying to discover. He frequently employs some descriptive statement, such as 'what you cut with' for scissors, or, in the case of color, may indicate how it is composed or the circumstances under which it is used. Verbal structure may suffer during the struggle to find the right word, but repetition is not materially affected; provided they are presented in articulated form, the sounds can be reproduced correctly. The essential defect is inability to fit a name to an object or an object to a name, to recognize the difference between words of contrasted significance and to execute promptly oral and printed commands. This disorder is mainly due to defective appre-

ciation of meaning and inability to evoke a desired name; both internal and external speech suffer as a secondary result.

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and 'time,' and knows that 'summer time' has something to do with the 'Daylight Saving Act,' he is unable to say if the clocks are put forward or back when it begins. He can carry out a maneuver where each action suggests the next, but fails to do so if he is compelled to formulate it to himself as a whole and is unable to bear in mind with certainty the final goal towards which his efforts are directed.

"He has no difficulty in forming words and can repeat what is said to him. But in general conversation his sentences tend to trail away aimlessly, as if he had forgotten what he intended to say. If he is told some simple story and is asked to reproduce it by word of mouth or in writing, many essential elements may be omitted; this occurs to an even greater degree after reading it to himself silently. He cannot retain the total conception of its meaning, which is necessary for perfect narration. He may be able to enumerate the details one by one correctly, provided he is allowed to mention them in any order as they may happen to recur in his memory; but his knowledge is episodic and is not co-ordinated by a general logically expressed formula.

"The clock tests reveal the nature of this disorder in a striking manner. The patient confuses the two hands, does not know how to approach the task of setting them to oral or printed commands, and forgets the meaning of 'past' and 'to' the hour. Even direct imitation on one clock of the time shown on another may lead to confusion; for, whatever the form assumed by the test, the patient is liable to misunderstand the intention of what he is asked to do. On the other hand, except in the gravest cases, he has no difficulty in telling the time, provided he is allowed to keep the clock in sight until he has given his answer.

"Such patients can write, but the result tends to be inaccurate and confused. Although spelling may be careless and the letters imperfectly formed, semantic defects are more liable to disturb the intellectual content and logical sequence of what is written than its verbal form. Not infrequently the written account of a set of ideas arising spontaneously, or suggested by something the patient has heard or read, trails away aimlessly just like the spoken narration of the same object. The power of reproducing a logical and orderly sequence suffers more severely than the direct act of writing.

"Counting is possible, and the actual value of numbers and coins may be recognized correctly. But the patient becomes confused if he is asked to state the relative value of two pieces of money; in daily life he finds profound difficulty in calculating the price of an article he has purchased, although he remembers how much he has expended. Arithmetical operations, such as addition and subtraction, are carried out uncertainly and with difficulty, because the nature of such mathematical processes is incomprehensible.

"Such patients fail to understand jokes which demand complete comprehension of printed words or pictures. They cannot play card games, draughts, or dominoes; nor can they put together puzzles, which confuse them greatly.

"Drawing, even from a model, shows considerable loss of general constructive power. These patients do not, as a rule, block out the drawing, but tend to begin at some one point and follow round the outline of the object detail by detail; this weakness of design is also evident when they try to reproduce it from memory. Attempts to draw an elephant usually end in confusion and occasionally the marks on the paper do not correspond to a coherent figure of any kind.

"None of this group could draw a plan spontaneously of a room with which he was familiar; unimportant details might be filled in, though salient features, such as the windows and doors, were omitted. This is not due to lack of memory of details, but to want of power to unite them into a coherent whole. For if I drew an outline plan and indicated upon it the position of each object as the patient pointed it out to me, he could subsequently reproduce this plan without fail.

"These patients are completely unable to find their way alone; they do not take their bearings and fail to recognize landmarks, or to appreciate that they are passing over ground that should be familiar. They do not know which way to turn, and if they chance to cross to the opposite side of the road become confused, ignorant in which direction to walk.

"Semantic disorders interfere seriously with the activities of daily life. The patient finds difficulty in collecting the subjects required to set the table for a meal, in adjusting the complexities of a military belt, or in putting together the different parts of a piece of furniture he has constructed. Such defects render him useless for any but the simplest employment; yet his memory and intelligence may remain on a relatively high plane. He does not forget people and places and his power of remembering detail is sometimes remarkable. He can recall spontaneously events both recent and remote and may be able to furnish valuable information with regard to his disabilities. It is not 'memory' that is affected, but the power to co-ordinate details into a general formula for external statement.

"The tendency to confusion and want of comprehension of what is going on around them leads these patients to seek solitude and to shun their fellows. In some instances this produces an odd form of behavior or even a definite psychosis."

The full direct quotation from Head's description of these disorders of speech has been given purposefully. It would be needless repetition to call attention to possible methods of re-educating these patients after they have been so clearly pointed out by Head. It should be emphasized that they are simple and can be carried out daily by the interested and intelligent co-operation of relatives.

TREATMENT OF LESIONS RESULTING IN SENSORY DISABILITY

Vascular lesions of the cerebrum which involve the posterior limb of the internal capsule are characterized by a spastic hemiplegia which is accompanied by a hemianesthesia upon the same side as the motor dysfunction. Intracranial tumors which involve the parietal lobe, that

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atonia are the most outstanding symptoms of cerebellar disease. Voluntary movements may be performed with excellent motor power but with marked incoordination and loss of the ability to measure accurately the range of movement. In general, lesions of the cerebellar hemisphere give rise to symptoms in the extremities, while the vermis of the cerebellum exercises a control over the trunk movements. However, not too much dependence must be placed in the exact localizing value of clinical signs, for very frequently a lesion quite discretely placed within one hemisphere may by its symptoms lead one to diagnose a midline tumor, and vice versa.

The affected limbs show a definite decrease of muscle tone and are flaccid and rather flaillike. The hand and fingers or the foot may be dorsiflexed or plantar flexed to an abnormal degree. If the forearm is held fixed at the elbow, it may be shaken so that the hand flaps about like a loose appendage. If the forearm is flexed strongly against resistance which is removed suddenly, the hand may be jerked toward the patient's shoulder with a grossly uncontrolled movement. This loss of check reflexes may be demonstrated in the upper and lower extremities in a variety of ways. If, for example, the knee reflex is obtained with the patient sitting and the lower leg dependent, the initial jerk is followed by many repeated oscillations before the leg finally comes to rest. Attempts to perform rapidly alternating movements with the hands are characterized by large, awkward, incoordinated movements upon the affected side.

Likewise, the tests for dysmetria or asynergia are characteristic of cerebellar dysfunction. If the patient attempts to place his forefinger on the tip of his nose with his eyes closed, the affected extremity misses the mark widely or there is a coarse ataxic tremor present at the end of the movement. The same loss of the ability to measure a movement may be shown by the test which requires the patient to place the heel of one foot upon the opposite knee, with the eyes closed.

The atonia and asynergia are exhibited in the drunken, swaying gait of the patients with cerebellar disease. The ability to balance themselves may be markedly affected. This may be tested by having the patient stand on one foot alone and unsupported. With the affected extremity raised, he will be totally unable to balance himself, and the affected extremity will describe large awkward arcs as he attempts to maintain his equilibrium. On the contrary, when he stands on the affected extremity with the sound one raised, he is able to balance himself much better.

In lesions which affect the vermis of the cerebellum, the patient may be wholly unable to sit erect, unsupported. The entire upper body may pitch forward, backward, and laterally in the attempt to remain upright.

Attention has been called to these signs and symptoms of cerebellar dysfunction because they point out quite simply and effectively the methods to be used in re-education. It must be emphasized that there

is, posterior to the central sulcus, produce sensory disturbances. This is also true of traumatic lesions which involve the same portions of the cerebral cortex.

All of these sensory changes differ considerably from those which accompany spinal cord or peripheral nerve lesions. Usually there is no gross loss of sensation in the sense of an absolute analgesia or anesthesia. There may be slight, if any, change in the patient's ability to oppreciate tactile, painful, or thermal stimuli. Rather, he may describe them as unnatural and be unable to localize accurately the site of the stimulus.

On the contrary, such a patient is unable to appreciate the sense of position or small movements of a segment of the limb. We have recently observed two patients with verified gliomas situated deep within the parietal lobes, and both complained of an inability to place themselves accurately in space. No doubt a part of this feeling of dissociation from spatial limits was due to an existing homonymous hemianopsia. The patient may be unable to recognize the size, shape, weight, or consistency of objects.

If the lesion involves the optic thalamus, the threshold for the reception of painful and thermal stimuli may be lowered greatly. The response is greatly exaggerated; so much so, that acute pain and suffering may result from insignificant stimuli. This type of paroxysmal or thalamic pain may resist all forms of active treatment.

While trophic ulcerations of the skin, characteristic of peripheral nerve lesions, are not present in cerebral lesions, the impaired circulation of the skin predisposes to decubitus lesions. Cleanliness, dryness, and the use of ultraviolet light on the skin are excellent prophylactic measures which may be employed when a patient is confined to his bed for a considerable period of time.

The re-education of sensory function may be undertaken upon the same fundamental principles already outlined for the treatment of motor disability. The patient may be taught to pick out various-sized coins or other objects upon command with his eyes closed. He may practice touching various parts of his body with the forefinger with his eyes closed. In a similar manner he may re-educate his sense of the appreciation of the shape of square, triangular, or rectangular wooden blocks. Various textures of pieces of cloth may be used for re-educational purposes. Here, again, all of these simple exercises may be multiplied many times and all of them may be carried out daily in the patient's home.

Cerebellar Lesions

The most common causes of cerebellar dysfunction are intracranial tumors in the posterior cranial fossa and traumatic lesions which produce direct injury of the cerebellum. Whereas cerebral lesions produce symptoms on the contralateral side of the body, cerebellar lesions are characterized by ipsilateral signs and symptoms. Asynergia and

atonia are the most outstanding symptoms of cerebellar disease. Voluntary movements may be performed with excellent motor power but with marked incoordination and loss of the ability to measure accurately the range of movement. In general, lesions of the cerebellar hemisphere give rise to symptoms in the extremities, while the vermis of the cerebellum exercises a control over the trunk movements. However, not too much dependence must be placed in the exact localizing value of clinical signs, for very frequently a lesion quite discretely placed within one hemisphere may by its symptoms lead one to diagnose a midline tumor, and vice versa.

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In lesions which affect the vermis of the cerebellum, the patient may be wholly unable to sit erect, unsupported. The entire upper body may pitch forward, backward, and laterally in the attempt to remain upright.

Attention has been called to these signs and symptoms of cerebellar dysfunction because they point out quite simply and effectively the methods to be used in re-education. It must be emphasized that there

is no paralysis present. Active voluntary movements are possible, but they are asynergic. We have been impressed with the striking results which have been obtained in our attempts to re-educate patients who have been operated upon for the removal of intracerebellar or cerebellopontile angle tumors. Simple exercises designed to re-educate coordination of their muscles and based entirely upon the characteristic signs of their dysfunction have been employed. It is quite true that in some instances former occupations which require finely controlled and coordinated movements cannot be regained, but gainful occupations which require less accurate movements may be opened to these patients.

We have employed such simple exercises as having the patient pick up a glass of water from the table, take it to the mouth, and replace it without spilling its contents. He must be shown how to do this in one continuous, smoothly coordinated act. He may be taught to practice walking along a straight line drawn on the floor, making certain that he looks ahead and not down at his feet. Again, he may practice the same acts which have been described as tests for cerebellar dysfunction. Here, as in cerebral lesions, results may be obtained more satisfactorily if purposeful exercises are employed to hold the patient's interest and to provide a goal toward which he may strive. Adult patients may be self-conscious in making their practice maneuvers before an audience, and it is important that the patient practice his movements with relaxation, self-confidence, and a feeling of steady attainment. Doubt or discouragement must not be allowed to develop in his mind. We have also employed motion-picture studies to show these patients the results of their persistent efforts.

Spinal Cord Lesions

The symptoms which result from involvement of the spinal cord are to be distinguished from those which result from injury or disease of the cauda equina. Spinal cord lesions are characterized by the symptoms of an upper motor neuron lesion. These are spastic paralysis, increased deep tendon reflexes, pathologic reflexes, absence of superficial reflexes, and absence of muscle atrophy and of the reaction of degeneration. In direct contrast, cauda equina lesions are essentially like peripheral nerve lesions in that the symptoms present are those of a lower motor neuron lesion. These are flaccid paralysis, muscle atrophy, the reaction of degeneration, and absence of deep tendon reflexes and of pathologic reflexes.

The motor dysfunction in either event is one which involves most commonly the lower extremities. A spastic or flaccid paralysis is, therefore, highly suggestive of spinal cord involvement. Lesions of the cervical segments of the cord may, of course, affect all four extremities and a quadriplegia results.

FIG. 3.—Marked flexor and adductor spasms and contractures which followed a gunshot injury of the spinal cord. This patient had received no physical therapy of any kind. While physical therapy is useful and necessary even at this stage of deformity, it is obvious that recovery of function is less probable than it would have been had proper care been given early to this patient.

SPASTIC PARAPLEGIA

The paraplegic state is analogous to the hemiplegic state described previously as the result of cerebral lesions. The gait of a spastic paraplegic patient is quite characteristic. When the feet are on the floor, they seem to be glued there. The upper portion of the body is inclined forward as the patient attempts to advance. The pelvis is elevated to one side while the corresponding extremity is dragged forward. Clonic movements of the limb may interfere with placing the foot upon the

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from the slightest to the most extensive in the different types of cases. A rupture of the intervertebral disk into the vertebral canal may in some cases, with the lesion being of large size and lying in the cervical or thoracic canal, cause spasticity of a certain degree.

Degenerative Diseases of the Spinal Cord.—The most common degenerative diseases which produce spastic paraplegia are lateral sclerosis; amyotrophic lateral sclerosis; posterolateral sclerosis, which accompanies pernicious anemia; syringomyelia; multiple sclerosis; and the familial ataxic disorders. In all of these diseases the lateral pyramidal tracts undergo progressive degeneration. The spasticity and paralysis develop gradually and insidiously.

In lateral sclerosis the degeneration is limited to the pyramidal tracts and sensory disturbances are absent. Only the lower extremities are involved, so that the clinical picture is one of a pure spastic paraplegia. In amyotrophic lateral sclerosis there is a concomitant lesion of the spinal gray matter of the cervical segments of the spinal cord. In this disease, therefore, there are the combined symptoms of a lower motor neuron lesion in the arms and an upper motor neuron lesion in the legs. The upper extremities present atrophy, loss of tendon reflexes, and flaccid paralysis, plus the reaction of degeneration. At the same time the lower extremities present the symptoms of a spastic paraplegia in varying degrees. Sensory symptoms are absent.

Pernicious anemia is the one disease which attacks the lateral pyramidal tracts and the fibers of the posterior columns of the cord simultaneously. The predominance of the paraplegic state over that produced by the posterior column disease similar to that present in tabes dorsalis, or vice versa, is dependent upon the extent of the pathologic processes. Subjective and objective sensory disturbances vary greatly in each case. Syringomyelia may produce a clinical picture similar to that seen in amyotrophic lateral sclerosis. In addition, however, there are marked sensory disturbances due to the involvement of the pain and temperature fibers as they cross in the anterior gray commissure. Multiple sclerosis is characterized by the scattered nature of the pathologic lesions present in the cord and medulla. Sensory disturbances may be present but are usually not well marked. The upper extremities are less frequently involved in the general loss of power. In both upper and lower extremities the weakness or paralysis is associated with a comparatively moderate degree of spasticity.

A group of cases has been described by a number of authors, beginning with Strümpell, which presents pure spasticity and familial traits. The spastic condition may appear at any age, and there is paresis only in the terminal stages of the disease. Increased tendon reflexes and hypertonicity of the muscles are the outstanding symptoms. Sensory and sphincteric difficulties are absent. The rigidity of the legs may be so marked as to make the gait spastic and walking impossible.

Trauma.—Injury of the spinal cord may be the result of direct trauma to the cord, as by a gunshot wound, a splinter of bone, con-

floor, so that the heel is elevated and the patient moves up and down on his toes. Finally, the limb becomes fixed, and the opposite extremity is advanced in the same manner. Frequently these short and jerky steps may be interrupted by violent overaction of the adductor muscles of the thighs which displace the knees inward. Sometimes a cross-legged or scissors gait is produced.

If walking is impossible, the same cross-legged attitude is characteristic of the patient as he stands. The tendency is for the knees to adduct and for flexion of the knee and hip joints to occur. The patient may flex his trunk far forward at his hips in his efforts to remain standing and to prevent these adductor and flexor spasms from causing him to fall.

When the patient is bedridden and a spastic paraplegia is strongly developed, the lower extremities may be extended rigidly. The adductor muscles of the thighs are strongly contracted and may cause the limbs to be crossed. The marked rigidity may cause the extremities to act like rigid pipes which are hinged together. Passive movement of one foot upward may be followed by a like movement in the other extremity because of this rigidity. In other severe cases of paraplegia, rigidity may occur in flexion. The legs are strongly flexed on the thighs and the thighs, in turn, may be so completely flexed on the trunk that the knees touch the patient's sternum. Commonly in such cases there is also a strong adductor spasm which makes these patients appear to be tied into a knot. It has been our observation that these flexor-reflex movements are initiated by the adductor spasm which is, in turn, followed by flexion of the limbs (Fig. 3).

The deep tendon reflexes may be exaggerated incredibly in these patients. The slightest touch may cause violent reflex movements which throw the patient about on his bed, or produce flexor-withdrawal reflexes which result in a posture similar to that presented by the patient with a paraplegia in flexion.

The bladder and bowels are affected to a variable degree in these cases. Lesions of the lumbar cord destroy the vesical and rectal reflexes, while involvement of the cord at higher segments removes the patient's control over these functions. Quite frequently patients may develop an automatic bladder which empties when its contents have reached a given amount. Mass reflexes may also be present in which the entire limb flexes upon stimulation; this is accompanied by expulsion of the contents of the bladder.

Sensory and trophic disturbances are variable, depending entirely upon the horizontal involvement of the spinal cord substance. Contractures may produce deforming postures which seriously cripple these patients and make operative measures necessary to afford them relief from their suffering.

Etiology.—The most common causes of a spastic paraplegia are (1) degenerative diseases of the spinal cord, (2) trauma, (3) tumors, (4) birth injuries, and (5) infectious diseases. The symptoms vary

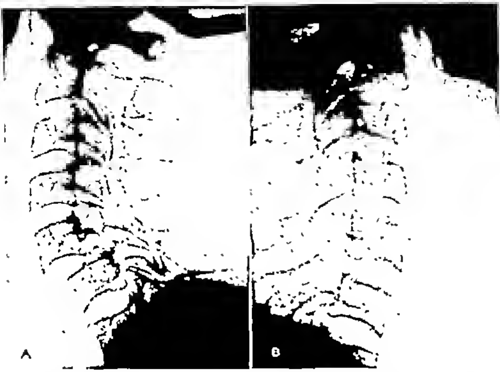

FIG. 4—*A*. Dislocation of the fifth upon the sixth cervical vertebra, together with comminution of the body of the seventh, producing an incomplete lesion of the spinal cord. (Before application of traction.)

B. The same patient, with the dislocation completely corrected. Twenty-four hours after the accident, when the patient was first seen, skull tongs were put in place and 20 pounds of traction applied. He was immediately relieved of neck and shoulder pain and soon showed signs of neurologic recovery. Note the increase in length of the total cervical spine after reduction. (Photograph taken three days after application of traction, with traction still in place.)

is more commonly observed, whereas, in incomplete lesions, frequently extensor types of movements are present. In complete lesions, the posture of the lower limbs is one of slight flexion; in partial lesions, extension. As a general rule, partial lesions of the spinal cord generally show a condition comparable to that of a decerebrate animal in which there are defense reflexes with marked spasticity. Although an extensor type of response to plantar stimulation has been observed in complete section of the spinal cord, usually such a stimulation is followed by a plantar flexion of the toes, and, as a fairly general rule, it may be stated that an extensor type of reflex is strongly indicative of an incomplete lesion. Inasmuch as prolonged states of toxemia or septicemia from urinary sepsis or bed sores hasten considerably the reappearance of reflex inactivity in cases of complete section of the spinal cord, it frequently occurs that, from the practical standpoint, incomplete lesions are relatively easily recognized by the long persistence of spasticity and signs of a paraplegia in extension. Of particular value in recognizing incomplete lesions is the early appearance of a Babinski sign, the failure to evoke mass reflexes from above the knee, a definite

cussion or contusion; or it may be the result of indirect trauma, as compression from a fracture-dislocation of a vertebra, or edema. Although hemorrhages and thrombi may abound at the level of the injury and to a distance of one or two segments above and below, a true hematomyelia is a rare occurrence.

Frequently severe injury and, at times, incomplete section of the spinal cord, have been observed with an intact dura mater. As in the case of peripheral nerve lesions, a complete physiologic interruption of the spinal cord cannot be differentiated from a complete anatomic one. Both are followed by complete paralysis in the muscles supplied by nerves originating below the level of the injury. In both, complete sensory loss results below the level of the segment, and the reflex changes and bladder disturbances may be similar. Although many cases of incomplete anatomic lesions of the spinal cord show complete physiologic interruption, a large number may be recognized by only partial paralysis of the muscles below the level of the lesion or by preservation of one or all types of sensibility. Prior to the Great War, Bastian's law—that, following a complete transection of the cord, flaccidity was present and all reflex action was lost—was almost universally accepted and seemed to afford a method for the easy recognition of this condition. Recent observations, however varying, have shown definitely that this law is untenable.

Symptomatology.—The symptomatology following a complete transection of the spinal cord may be divided into three stages. First is the stage of muscular flaccidity, corresponding to the period of spinal shock, in which the paralyzed muscles are toneless and flabby and all reflexes, superficial and deep, are usually absent, with retention of urine and feces. At times retention of urine and incontinence of feces have been observed and at times the cremasteric and bulbocavernosus reflexes have been elicited. The second stage, the stage of reflex activity, begins with the first reflex response to an external stimulus, usually from the sole of the foot. In the full development of this stage, a stimulus applied to any part of the lower extremity gives rise to a flexion reflex of the hip, with adduction of the thigh, knee, and ankle. When reflexes can be evoked with ease, an extensive and widespread reflex action can be obtained which has been called a "mass reflex." This consists of a flexion spasm of the ventral abdominal wall and of the lower extremity, evacuation of the bladder when its contents accrue to a certain amount, and sweating from an area of the skin in the paralyzed region. One of the most receptive fields for exciting reflexes is the genital area. During this stage, in some cases the knee and ankle jerks can be evoked. Under favorable conditions, an automatic function of the bladder and rectum may be established, usually in the third week. The third stage, that of gradual failure of reflex functions of the isolated spinal cord, usually preceding death, consists of a gradual return to a condition closely simulating the first stage.

Certain differences of reaction in complete and incomplete lesions may be pointed out. In complete lesions, the flexor type of movement

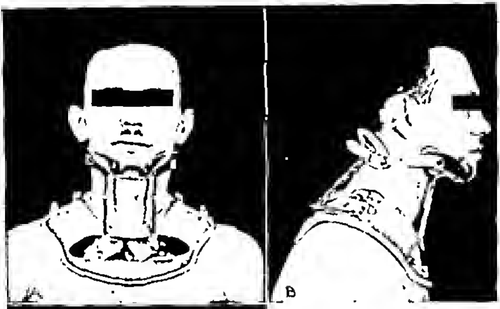

FIG. 6.—A very satisfactory neck brace, with adjustments to increase support on the occiput and mandible. Such a brace is useful in maintaining position of the cervical vertebrae after skeletal traction has been discontinued. With such support the patient may then be out of bed.

The spastic paraplegia is usually of gradual development in compression of the cord due to tumor masses, although occasionally one may see the sudden onset of paraplegia due to erosion and collapse of a vertebra by a tumor mass or as the result of a sudden dislocation of a tumor within the vertebral canal. We have also seen this happen in young patients who suffered a spread downward in the cerebrospinal axis of a rapidly growing medulloblastoma in the posterior cranial fossa. Root pains which surround the trunk or radiate into the limbs may be early symptoms. Complaints of heaviness, weakness, and clumsiness of the legs may be made long in advance of paralytic symptoms. Tingling or "electric" pains are frequently complained of, and each

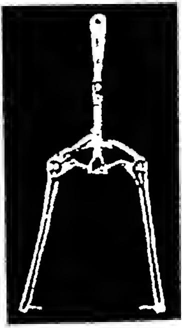

FIG. 5.—Skull tongs which are placed in the outer table of the skull at the superior temporal line above the ear. The swivel handle allows free motion for the application of traction weights (18 to 20 lbs.) and for moving the patient. Such skeletal traction should be applied as soon after a cervical fracture-dislocation as possible, and it should be maintained continuously for 25 to 30 days.

history of an absence of a state of spinal shock, marked tonicity in the paralyzed extremities, the involvement of both flexors and extensors in reflex movements provoked by the stimulation of receptive fields, and, of course, in obviously incomplete lesions, the absence of total paralysis or anesthesia below the level of the lesion.

Fracture-dislocations of the cervical vertebrae, with cord damage, present a somewhat specialized problem in the traumatic group. The injury is frequently at the level of the fifth and sixth vertebrae, with a resultant paralysis of all the muscles of respiration save the diaphragm. If the lesion is a physiologic one, and it frequently is, the entire symptomatology may change within a day or two after mechanical correction of the deformity. We have used skull tongs with good success in such cases, and if adequate weight is used for traction there is a rapid return to normal bony alignment in the fresh injuries, with an immediate relief of shoulder and neck pain and the appearance of signs of neurologic recovery (Figs. 4–6).

TUMORS.—Spinal cord tumors may be intramedullary or extramedullary in location. The extramedullary tumors may be intradural or extradural and may produce compression of the spinal cord at any point about its circumference. Intramedullary tumors of the cord may simulate any of the degenerative diseases of the spinal cord in their symptomatology. Extramedullary tumor masses may arise from the meninges of the cord or from the vertebrae.

motor neuron lesion. The deep tendon reflexes are absent, there is muscle atrophy, the reaction of degeneration is present, and sensory changes form a prominent part of the clinical picture. The cauda equina of the spinal cord is involved in the pathology of these lesions. Their resemblance to peripheral nerve lesions is striking.

The most common etiologic factors which produce a flaccid paraplegia are fracture-dislocation of the lumbar vertebrae and tumors of the cauda equina. Here must be included, also, the ruptured intervertebral disk which is so commonly found between the third and fourth lumbar vertebrae or between the fourth and fifth. Anterior poliomyelitis which produces the syndrome of a lower motor neuron lesion should also be included in the etiology of flaccid paralysis of the lower extremities. In this disease there is a total absence of sensory disturbances. The varying degrees of paralysis which may result from this disease and the late treatment of this condition are considered in Chapter 8 and therefore will not be considered here.

TREATMENT OF SPASTIC AND FLACCID PARAPLEGIA

The treatment of spastic and flaccid paraplegias as the result of spinal cord and cauda equina lesions by the use of physical therapeutic means may be considered together. The differences in the treatment of the spastic and flaccid paraplegic states may be emphasized as each type of therapy is discussed. The results of physical therapy in the treatment of flaccid paraplegia are much more satisfactory than those which can be obtained in spastic paralysis.

Massage.—Just as in the spastic limbs of the hemiplegic patient, so in spastic paraplegia, reflex activities are heightened. The slightest touch may produce marked adductor and flexor spasms. Consequently, massage in these cases must be very gentle and should consist of stroking rather than rubbing movements. On the contrary, massage may be more active and may be more effective in cases of flaccid paralysis. Massage may be begun with a period of rhythmic superficial stroking. Following this all of the muscles of the extremity should be massaged with a centripetal motion to affect the venous and lymphatic circulation. More pressure may be used than at the beginning of the massage, but care should be taken not to injure the paralyzed muscles by compressing them against bones. This may be increased gradually until the massage consists of a gentle kneading.

Massage should be preceded by exposing the extremities to heat for twenty to thirty minutes. This is particularly useful in flaccid extremities. Radiant heat, the infra-red light, hot packs, or a whirlpool bath of warm water are all useful, but they should be used with extreme care because of the ease with which the skin of a denervated area can be burned. The whirlpool bath, if it can be used without too much difficulty, is preferable because the motion of the water acts as a gentle massage.

patient will describe his paresthetic sensations in his own particular terminology. As pressure upon the cord increases, compression of the pyramidal tracts occurs and spastic paralysis and increased tendon reflexes appear. Spasticity, marked reflex movements, and muscular rigidity with contractures may become very pronounced in these types of slow cord compression. Sphincteric loss is a late feature of these cases and is usually preceded by lesser degrees of incontinence. Sensory disturbances vary in direct relation to the degree of involvement of the afferent fiber tracts in the cord. Trophic disturbances of the skin are quick to develop in the presence of poor nursing care and prolonged periods of confinement in bed, and it is to the interest of everyone concerned that such lesions do not develop in these patients who are always a great nursing care and whose eventual outlook may be precarious enough because of their spinal cord lesion alone.

Birth Injuries.—A very important cause of motor disability in children is caused by injury to the spinal cord as the result of obstetric accidents. In the opinion of Crothers [4] the majority of cases are due to the "imposition of the unphysiologic force of traction." Crothers emphasizes the fact that the management of these children depends upon the intactness and re-education of the physiologic residue rather than upon the exact nature of the anatomic lesion. If the lesion is confined to the spinal cord, the child at least has the advantage of a proper mentality. The most common deformity presented is paraplegia, but the clinical picture may vary enormously with the degrees of partial injury which may be present. The least favorable cases are, of course, those with physiologic or anatomic destruction of the lumbar enlargement of the cord. Urinary sepsis and trophic ulcers complicate the care of these patients. Complete flaccid paraplegia may be present in some cases due to an almost complete destruction of the lumbar spinal cord.

Infectious Diseases.—A large number of spinal cord lesions have been grouped under the term "myelitis." Inflammation of the cord substance is probably never primary. Infection may reach the cord by the vascular supply and not infrequently follows the exanthematous and septicemic diseases.

Acute cases produce the maximum damage in a few days; others require weeks. If death does not result, gradual improvement may occur. Decubitus lesions are serious complications in these cases. When spasticity develops, there is rarely any recession, and the paraplegic state which has been described results. Localized muscle atrophy due to involvement of the anterior gray matter never improves.

FLACCID PARAPLEGIA

In direct contrast to the spastic paraplegic state is a paralysis of the lower extremities, which is completely flaccid. As was stated previously, such a flaccid paraplegia presents the symptoms of a lower

neuron is uninjured, the trophic nerve supply to the muscles is intact and the intelligent employment of massage and active and passive movements will accomplish more with far less danger of harmful results.

On the contrary, in the flaccid paraplegias, electrotherapy may be used to great advantage. Electrotherapy is indicated to prevent the atrophy of muscles and fibrosis, to increase nutrition, and to conserve the functional capacity of paralyzed muscles until sufficient return of function has taken place to permit of active motion.

Since the days of Duchenne, neurologists have agreed that electrotherapy is of service in hastening the return of function in muscles paralyzed as the result of lesions of the lower motor neuron. Although some physiologists have felt that it was useless, others have shown by experimental studies that there is a sound basis for the belief that electrotherapy is of distinct benefit. Recently it has been shown, particularly in peripheral nerve lesions, that a more advanced type of regeneration of the nerve occurs when the denervated extremity is treated by electrotherapy.

It is necessary to understand clearly the method of action of treatment by electricity. Stimulation by an electric current of sufficient strength produces a contraction of the muscle. It is this active contraction which conserves the volume and nutrition and keeps the muscle fibers in a functional state adequate for voluntary movement when regeneration occurs. The only requirement of electrotherapy is that it produces a contraction of the paralyzed muscle. This cannot be produced by the faradic current because the duration of each stimulus is too short in relation to the changed chronaxia of the nerve and muscle. Galvanic current must be used, therefore. It may be used in its simplest form of a continuous current, with a make and break key, or in the form of sinusoidal currents of various wave types.

It has been said that a continuous current which produces a sharp contraction at the make or break is of little value because it does not resemble the normal contraction of a muscle. On the other hand, it is said that the sinusoidal current produces a slow contraction which is more nearly normal. Physiologic experiments have never shown that muscles contract slowly in their normal state. It may be accepted that the muscle contractions which result from the interrupted galvanic current stimulation are as useful as any other type of galvanic current.

The rapidity of the muscle contractions can produce no harm after the second week following injury or surgical procedures. During the first two weeks the muscles should be kept at rest. After this period, sudden contractions are as useful as slow ones. The force of the contraction may be modified by the strength of the current. Interrupted galvanic current is often painful, and therefore other types of waves are useful in children or sensitive patients. Since the muscle contraction occurs only upon making and breaking the current, prolonged stimulation is unnecessary. The current should be applied with short makes and immediate breaks by the use of a suitable electrode.

Active and Passive Movements.—Here, again, spasticity may interfere seriously with attempts to use active and passive movements in the treatment of a spastic paraplegia. Often when the patient attempts to perform an active movement, the spasticity of the extremity becomes so marked that the limb becomes rigid, stiff, and immovable. This is particularly true if the patient is not relaxed completely or if he feels that the movement must be performed upon command. Consequently, active movements in spastic patients must be begun slowly and very gradually, and unusual patience on the part of the patient and the nurse is imperative.

This is not true of flaccid paralysis. Active movements must be attempted and may be pushed as rapidly as the patient's progress permits. It is wise to aid the patient if necessary, so that the complete range of the particular movement is performed. Movements which occur reflexly in spastic paralysis must be differentiated from true voluntary movements and must not be interpreted as evidence of return of motion.

Passive movements may be employed to greater advantage than active movements in spastic extremities. They must be used carefully and gently, however, so that large defensive reflex movements may not be excited. As Langley [8] has pointed out, intermittent passive or active stretching forces lymph, and so presumably metabolic products, from the muscles. Moreover, such active or passive movements have a distinct influence upon the formation of connective tissue, the formation beginning rather quickly in lower motor neuron lesions. Part of the late contractures in flaccid paralysis may be due to the shrinkage of this newly formed tissue which is soft and extensible. Active or passive movements will stretch the developing connective tissue fibers so that, when they do shrink, there may be less tendency to a contracture.

Passive movements may be carried out very well in conjunction with massage. They help to stretch contractures which have already occurred and to prevent those which invariably occur in an inactive or denervated muscle. They also increase the range of motion in an already stiffened joint and help to keep a mobile joint active so that, when the time comes, it is ready to perform its part as an effective mechanism. Finally, such movements help to re-educate the muscles in performing normal movements. Each separate passive exercise should be individualized and the patient should be required to make the attempt to perform the movement simultaneously or to attempt to hold the part in the position imposed upon it.

Electrotherapy.—The use of electrotherapy in spastic paraplegic patients accomplishes very little as compared to the results which may be obtained in the flaccid paralysis. As a matter of fact, the heightened reflex activities of the spastic extremities may offer strong contraindications to its use. In upper motor neuron lesions, muscle atrophy does not occur except as the result of nonuse. Since the lower motor

FIG. 8.—Thomas type of calliper splint, which may be modified as desired for a paralysis of the lower extremity.

Contractions of muscles produced by electric current are a valuable aid to re-education and active motion. Although the patient may not be able to produce dorsiflexion voluntarily, the ankle may be held in that position after electrical stimulation has produced dorsiflexion.

FIG. 7.—A simple spring splint to aid in dorsiflexion of the foot and to prevent footdrop

During the first few months following the paralysis, the muscles are hyperirritable. Unipolar stimulation will produce contractions in the muscles most affected by the weakest currents, because of longitudinal stimulation. Consequently, fatigue in these muscles must be avoided. Deep muscle sense may be defective and the patient is unable to tell when his muscles are fatigued.

Later the most affected muscles become less irritable and unipolar stimulation produces a spread of current to unparalyzed muscles which alone may contract to the injury of the patient. Therefore, bipolar electrodes should be used at this stage. Although polar inversion does not always take place in degenerated muscles, it occurs in such a large number of cases that the positive pole should be used as the active electrode. It is also the least painful.

In producing contractions of the paralyzed muscles, care must be used to prevent the force of gravity from acting against the contracting muscles. This factor may hide movements of segments about the joints and may increase the onset of fatigue. The extensors of the foot may not produce a movement with the extremity in a position of footdrop, but if the patient rests the leg on a board at the outer surface, dorsiflexion may occur.

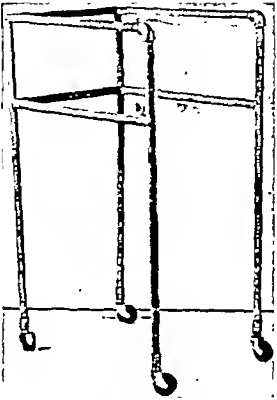

FIG. 10.—A simple type of walker, made of ordinary gas pipe and large ball-bearing casters, very useful in the first walking attempts of a paraplegic patient.

so that it may prove more desirable to use light crinoline posterior molded splints which may be removed easily for massage and passive movements. There is no reason for using heavy plaster-of-Paris boots which are out of all proportion to the effect desired. Adhesive tape straps from the sole of the foot to the dorsum of the leg may also be effective.

When the patient becomes ambulatory, the most satisfactory splint to prevent footdrop is one patterned after that shown in Figure 7. This is a simple device and can be attached to the shoe easily. As is usually the case, the remainder of the extremity also requires support. A modification of the Thomas caliper splint may be employed (Fig. 8). A spring lock at the knee joint enables the patient to flex the knee when he sits. When he is standing or walking, this lock closes and the knee is kept in extension. The additional footdrop splint may be attached very simply to this type of apparatus. Figure 9 illustrates another variety of splint which may be used when the residual paralysis affects the lower leg predominantly.

Exercise and Muscle Re-education.—Very often the paraplegic patient is looked upon by his physician with the same air of hopeless-

FIG. 9.—A splint for use in paralysis of the lower leg combined with a footdrop. The principle of such a splint is easily varied to suit individual needs.

Care must be exercised in treating areas of skin in which sensation has been destroyed. Burns are produced easily, and when ulceration once occurs, healing is difficult.

When the nerves and muscles have recovered sufficiently to contract to faradic stimuli, both galvanic and faradic stimulation are advisable, the purpose of the latter being to produce more prolonged or tetanic contractions.

Splints.—We have found splints of little or no use in the treatment of spastic paralysis of the lower extremities, once it is developed. Deformities and contractures may in part be prevented from developing by massage and passive movements of the joints. When the patient is confined to bed, the extremities should be kept in extension and in abduction by the use of sandbags and pillows. The feet may best be held up in a functional position, in order to overcome a forward drop of the feet, by a foot board which can be moved up and down the frame of the bed to accommodate to the position of the patient in bed.

On the contrary, much can be done by the intelligent use of splints in cases of flaccid paraplegia. While the patient is in bed, footdrop may be avoided by the use of sandbags against the soles of the patient's feet and a cradle over the legs to keep the weight of the bedclothes off the feet. These require careful and constant adjustments,

FIG. 11.—A walking frame combined with mirrors is a useful agent in re-educating a patient to walk.

floor of this aisle consists of a board upon which are painted square spaces which are numbered. These vary in size. The patient attempts to place his feet within these spaces, and as his skill develops, the wider spaces are utilized. The results of this method may be increased by having the patient observe the movements of his legs in a mirror (Figs. 11, 12).

We have also found that the movements of the lower extremities may be more easily performed in slightly warm water. This is true of the cases of spastic as well as flaccid paralysis. A Hubbard tank (Fig. 13) is an excellent means of carrying out these underwater movements. Since the tank may be installed in the basement of the patient's home and is relatively inexpensive, it is extremely valuable.

These few examples of methods of re-education of the muscles of the lower extremities may be multiplied many times. In more advanced cases, a stationary bicycle may be used or a rowing machine may be employed to advantage. Just as in the re-education of the upper extremities, productive educative exercises for the lower extremities intrigue the patient and secure his whole-hearted co-operation.

FRÄNKEL EXERCISES.—Though not strictly a spinal cord disease, tabes dorsalis produces ataxia in the lower extremities which may be

FIG. 11.—A patient engaged in walking exercises, stepping on markers designed for graduated active exercise.

ness as is the hemiplegic one. Many times massage, active and passive movements, electrotherapy, and splinting are carried out quite effectively until the patient is ambulatory, and then his further treatment is neglected.

It is necessary to teach the recovering patient to use his recovering muscles to his best advantage. He must be taught to walk again. While one may feel that this will be accomplished gradually in spite of what may be done, our cases have progressed more rapidly as the result of directed muscle exercises and re-education.

One of the simplest devices to teach the patient to use his extremities may be made of small iron pipes and is similar to a baby's walker. The patient stands within this frame, which is on rollers, and rests his weight upon his arms, grasping the sides with his hands (Fig. 10).

Another excellent method of re-education in walking is to have the patient walk in an aisle bounded by iron pipes, which may be grasped easily, and upon which he may rest his weight as he progresses. The

4. In the standing position the patient should place one foot in front of the other. With his hands across the chest, he should flex his knees and then slowly raise himself.

5. The second exercise may be repeated and extended so that the patient places one foot behind the other. This requires and educates the sense of balance.

6. With the feet together, the patient should stand alone with his hands on his hips.

7. With the feet separated in a normal position of standing and without a cane, the patient should perform various acts with the hands and arms.

These exercises may be lengthened and enlarged as the patient develops his coordination and, of course, are as valuable in cases of flaccid paraplegia of spinal cord origin as they are for patients with tabes dorsalis.

Surgery.—Marked deforming contractures may follow neglected cases of spinal cord involvement. Attention has been called to the flexor and adductor contractures in spastic paraplegia. Division of tendons, peripheral nerve section, such as severance of the obturator nerves in adductor spasm, and extensive posterior spinal root sections must be considered as a part of the treatment of these cases. Often a bedridden patient may be made ambulatory by posterior root section. After such a procedure the patient must be trained thoroughly and persistently by re-educational exercises and other physical therapeutic methods.

Modification of Treatment Because of Sensory Disturbances.—The loss of sensation is variable as a result of spinal cord lesions. Cauda equina involvement is characterized commonly by sensory loss about the buttocks. This has given rise to the term "saddle anesthesia."

Because of the sensory disturbances present, extreme care must be taken to avoid decubitus lesions of the skin of the back and buttocks. The skin must be kept scrupulously clean and dry. Alcohol rubs and the application of cocoa butter should be used freely. If possible, the patient should be turned on the side and propped there by pillows, so that strain on the paravertebral muscles is avoided. This distributes the pressure of the body over various areas of skin and allows the back to be treated efficiently.

Harsh, stiff linen sheets which burn the skin must be avoided. The linen must be changed immediately if it becomes soiled from an incontinence of urine or feces.

Decubitus lesions may be treated with excellent results by a few simple procedures at the patient's bedside. Care should be taken to débride the ulcers of all necrotic tissue. Undermining, sloughing pockets of dead tissue should be searched for and removed. After such débridement, the wound may be gently cleansed with plain soap and water and irrigated with normal saline solution. It should then be dried

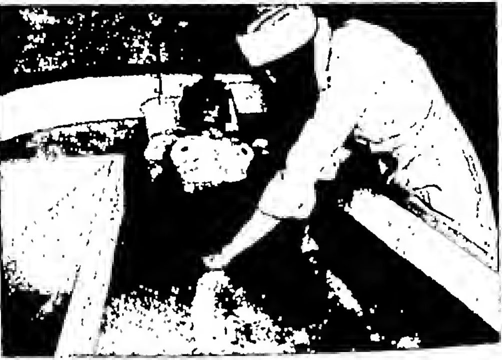

FIG. 13.—Patient performing exercises under water in a Hubbard tank.

treated very successfully by a system of re-educative exercises just described. There is a considerable amount of literature concerning the results of treatment of tabes dorsalis by Fränkel exercises.

Fränkel[9] has described two classes of exercises—those for bed-ridden and those for ambulatory patients. In bed, the patient is taught to flex, abduct, adduct, and extend each leg separately and both legs simultaneously. The knees and hips are also exercised. The patient should place the heel of one foot on the knee of the opposite leg and then pass it slowly down the tibia toward the ankle. These exercises should be carried out with the eyes opened and closed. They may be repeated twice daily for as long a time as the patient's condition justifies.

For ambulatory patients, Fränkel has described the following valuable series of exercises:

1. The patient is placed with his back to a chair and then, with his heels together, is asked to lower himself slowly into the chair and to rise in the same manner. Crutches or canes should not be used. It may, however, be necessary at first to provide the patient with the support of an attendant.

2. One leg may be placed at the distance of an ordinary walking step in front of the other and then returned accurately to the original position. The patient may support himself during this exercise, if necessary, with a cane.

3. The patient is asked to walk several steps slowly and with precision.

A laminectomy was performed and the compression due to the bony fragments was removed. For the last two years the patient has received massage, active and passive movements, electrotherapy, and re-educative exercises. He is now able to walk with the aid of crutches. His ability to stand with the support of his crutch, at the end of the two-year period, is shown in Figure 13. Persistent daily re-educative exercises at home played a very important part in this man's rehabilitation, and he was seen at frequent intervals after his discharge from the hospital, in order that new exercises might be provided as his condition improved.

H. S., a 48-year-old housewife, was injured in an automobile accident and suffered, among other injuries, a fracture-dislocation of the fifth cervical vertebra. She immediately showed signs of a physiologic lesion of the spinal cord, with only a slight amount of motion in the arms and hands. The legs were completely paralyzed. For four months she had no treatment of any kind, and no attempt was made to reduce the fracture while it was still fresh. The improvement in her condition during that period was essentially nil. When she was first seen in this clinic, it was discovered that she not only had an incomplete lesion of the cord but also a complete subarachnoidal block. The dislocation had existed for too long a time to make reduction possible; therefore, a laminectomy was performed. Immediately her symptoms began to disappear. She was started upon a course of systematic physical therapy including heat, massage, active and passive exercises. Her recovery was so rapid that she was discharged from the hospital fourteen days after the operation, and in three weeks from the date of discharge she walked into the office for a check-up visit. Physical therapy has been used continuously until the present, with special emphasis on re-educative active, purposeful movements. Now, less than one year after operation, she walks alone without a cane or other support of any kind, and she can use both hands accurately and normally except for a few fine movements.

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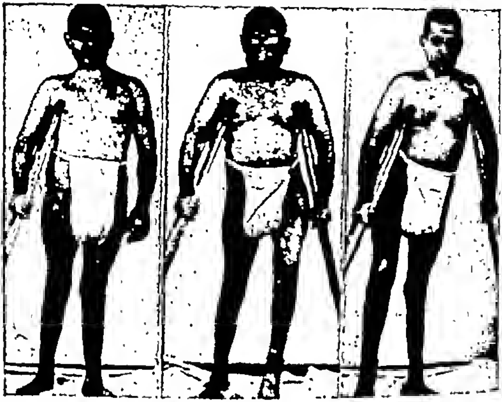

FIG. 14.—Flaccid paraplegia which resulted from a fracture-dislocation of the third lumbar vertebra. The patient regained the use of his lower extremities following persistent and intensive physical therapy.

with a simple heat lamp and left exposed as long as possible to the open air. Only aseptic surgical technic should be used in the treatment of such ulcers, and *daily* care is imperative. Frequent exposure to ultraviolet light has been of great aid in the rapid healing of such lesions in our patients.

In many spinal cord disturbances, perforating ulcers of the large toe and heel occur. These, too, must be kept clean and free from infection. They are usually painless and begin as a callus or corn. Ulceration follows, and, if untreated, the bone may become denuded. Dry heat and ultraviolet light exposures aid materially in keeping these lesions dry and clean.

Report of Cases.—The results which may be obtained by the persistent use of these therapeutic measures in spinal cord injuries may be illustated by a brief recital of the following cases:

C. D. (Fig. 14), aged 46, received a fracture-dislocation of the third lumbar vertebra in an automobile accident in 1929. There was an immediate flaccid paralysis of both lower extremities. There was incontinence of urine and feces and there was loss of sensation over the area supplied by the fifth lumbar and all the sacral segments of the cord. Six weeks elapsed after his injury before he was brought for surgical treatment.

CHAPTER SIXTEEN

PHYSICAL THERAPY IN BACK INJURIES

HARRY E. MOCK, M.D.

GENERAL BACK INJURIES

Backache is one of the oldest complaints of the human race. Failure of our profession to solve more thoroughly the cause or causes of this condition and to relieve adequately the sufferers from back pain has made this one of the most fertile fields in the category of human ailments for exploitation by the many unqualified to treat the condition. It is not the purpose of this chapter to offer physical therapy as a "cure-all" for these back conditions.

For the physician who is seeing the occasional back condition, or who is unfamiliar with the rather intricate methods of diagnosing or differentiating between the various back lesions, physical therapy may come as a new and easy experiment to be tried out on such cases. Undoubtedly a certain per cent of his patients will be benefited, but a large per cent will be unrelieved and disgruntled not only with the physician but with the method.

For the physician who is prone to diagnose low back pain as a "sacro-iliac disease," or a painful back following injury, with negative x-ray findings, as a "back strain," or a "slipping vertebra" or "slipping sacro-iliac," and who has developed the habit of treating all these conditions by the rather simple method of applying a back brace or a special belt, physical therapy may be frowned upon as a time-wasting, needless procedure. True, rather a high percentage of his cases may be relieved of their back pain, but in a large number such a procedure gives too prolonged a disability and leaves many a working man more or less permanently disabled, due to the stiffening of the back muscles, ligaments and aponeuroses.

For the surgeon who is thoroughly versed in the diagnosis and treatment of back lesions, who has tried out all the old methods of traction, casts, sacro-iliac belts and back braces, and who has seen the high percentage of failure to relieve many persistent low back pains, or to prevent permanent disability in many compression fractures, there has been a growing tendency to resort to operative procedure, viz., bone grafts, or other bone-bridging methods. Such a one, if he has become wedded to operative procedures, may fail to give the time and energy necessary to carry out a thorough course of physical therapy before subjecting his patient to surgery.

From the advertisements in lay journals and from some of the therapeutic claims made by the manufacturers of certain physical therapy apparatus, it is evident that the pretensions of this form of therapy equal or surpass the fraudulent claims made for drug therapy in the palmy days of patent medicines.

It may be asserted that the medical profession has no priority rights to massage, electrotherapy, mechanotherapy, or other physical therapy measures, but when it comes to dealing in human health and human life, no lay institution and no individual, be he physician or otherwise, has a moral right to practice this or any other form of therapy without a thorough knowledge of diagnosis and an adequate understanding of the given therapy.

Review of the medical literature of the last two decades reveals the vast amount of thought and effort that has been given to this question of disabling back conditions. Many theoretical explanations have been advanced by various authors to explain the causes of disabling back conditions, especially the low back pain. These theories have been adopted as positive facts by the profession. Thus we have run the gauntlet of "sacro-iliac slipping," "sacro-iliac sprains," or "sacro-iliac disease or displacements." Then came the diagnosis of "lumbosacral sprain" and its differential diagnosis from "sacro-iliac sprain." More recently the weight of opinion has swung from this mechanical or anatomic explanation for these conditions to a systemic or toxic basis, and thus the theory has been advanced that the true cause for many of these low back pains is a "myofascitis." Still more recently we find great weight being given to faulty posture and to the abnormal anatomic construction of the spine. During the last two years almost every report of a roentgenogram of the back refers to the relationship of the fifth lumbar vertebra and the sacrum, and a faulty angle at this joint is frequently assumed to be the cause of the trouble.

Many of these diagnostic titles are still recognized by the profession as real conditions, while others have been discarded or are not recognized as of real importance.

Schaufller [1] sums up the situation as follows:

> Careful attention to the history and to the mode of onset and course of the back pain will help to decide whether one is dealing with a sprain or a mechanical strain. For years sacro-iliac displacements or sprains have been overplayed. Then the honors were divided between lumbosacral and sacro-iliac sprains or they were simply said to be a low back sprain. Now the pendulum has swung far to the opposite side and many articles in recent literature claim that all these back pains are toxic. Myofascitis is the popular term.
>
> As always, the truth lies between the extreme views. There are lesions purely mechanical and any associated inflammation is of a traumatic type and not at all of a bacterial type. There are many others which are purely

The physician who is willing to treat back lesions, although he is not completely satisfied with his diagnosis, too often uses inadequate physical therapy measures because he likewise has an unsatisfactory understanding of real physical therapy methods. Thus, I have seen patients who for months have gone to physicians for only diathermy treatments or for light treatments without receiving any benefit.

The physician who is accustomed to use back braces or special back belts will find physical therapy, if used properly and for the purpose of maintaining function in a group of joints that are held immobilized by the mechanism, an invaluable adjunct to his usual procedure.

Most surgeons hesitate a long time before ankylosing one of the joints of an extremity. Two or three joints of the back, however, can be ankylosed without any great loss of function because of the great number of back joints. The loss of function, when resulting, usually comes from the prolonged fixation of the after-treatment. Nevertheless, this operation on the back is an extremely major affair, fraught with real dangers in many of our hands, and should be used only as a last resort. The usual nonoperative surgical procedures, combined with carefully supervised and adequate physical therapy, will obviate many such operations. When it is necessary and is performed, the same carefully directed physical therapy will prevent loss of function in the remaining back joints and will hasten the ultimate recovery.

During the last decade, physical therapy has received very extensive consideration by the medical profession. Many rather extravagant claims for its usefulness have been made within the profession, as well as from many sources outside the profession. Some form of physical therapy, usually requiring complicated and often expensive machines for its administration, has been advocated for almost every known disease. Here again these back conditions have proved a fertile field for the so-called "physiotherapist."

Almost every community of any size now has one or more nonmedical institutions for the administration of various forms of physical therapy. Here is an actual advertisement typical of such institutions:

KEEP FIT

WITH

ELECTRICAL CABINET TREATMENTS
COLONIC THERAPY
MEDICAL MASSAGE
HYDROTHERAPY
ELECTROTHERAPY
CORRECTIVE GYMNASTICS
WEIGHT CORRECTION
VAPOR AND SULPHUR BATHS
X-RAY TREATMENTS
MEDICAL BATHS

therefrom, and consequently injuries of the spine are liable to be complicated by involvement either of the spinal cord itself or of the emerging nerve roots. Furthermore, it is probably owing to the presence of the spinal cord that injuries of the spine are particularly liable to be followed by functional disorder.

Musculature.—The apparently complicated arrangement of the muscles of this region may be partly simplified by dividing them into separate layers. Of these, the first two appertain to the upper extremity, including the shoulder girdle, and the fourth and fifth layers are more truly spinal.

First Layer: Trapezius, latissimus dorsi

Second Layer: Levator anguli scapulae, rhomboids

Third Layer: Serratus posticus superior and inferior, splenius colli, and capitis

Fourth Layer: Sacral and Lumbar Regions—Erector spinae

Thoracic Region: Iliocostalis, accessorius, longissimus dorsi, spinalis dorsi

Cervical Region: Cervicalis ascendens, transversalis cervicis, trachelomastoid, complexus, biventer cervicis, spinalis colli

Fifth Layer: Semispinalis dorsi, semispinalis colli, multifidus spinae, rotatores spinae, interspinales, extensor coccygis, intertransversales, rectus capitis posticus major and minor, superior and inferior oblique

At first sight such a bald recital of the different muscles as given in textbooks of anatomy is confusing and even irritating. Let us, therefore, endeavor to simplify the problem as follows:

Fourth Layer: The "erector spinae" has a strong tendinous origin from the iliac crest, the sacrum, and the lumbar spines, and divides into three muscular masses.

The outer—the sacrolumbalis, with its prolongations, musculus accessorius, and cervicalis ascendens—is attached to the angles of the ribs.

The middle—the longissimus dorsi, with its prolongations, transversalis, colli and trachelomastoid—is attached to the transverse processes of the vertebrae.

The inner—the spinalis dorsi, with its prolongations—is attached to the spinous processes of the vertebrae.

Fifth Layer: The greater part of the muscles constituting this layer forms a mass which fills the space between the transverse and spinous processes of the vertebrae, and the general direction of the fibers is oblique. The intertransversales pass between the transverse processes of adjacent vertebrae and the interspinales, between the spinous processes. The semispinalis dorsi and colli, the multifidus spinae, and the rotatores spinae pass obliquely between the transverse processes and the vertebral spines. The more superficial bundles pass over several vertebrae, while the deeper bundles pass between adjacent vertebrae.

Lumbar Aponeurosis.—Many cases of prolonged disability are caused by injuries of this aponeurosis, or, rather, by injudicious treatment of such injuries by prolonged rest until adhesions and scar tissue have formed in and about this structure or its extensions.

toxic; a myofascitis or arthritis is similar to muscular or joint rheumatism in the limbs or to a toxic neuritis. In the back there is also a large group of a mixed type. Posture was a predisposing cause, or injury an exciting cause, but the toxic element is responsible for the continuance of the trouble.

It is evideot therefore that before an adequate line of treatment can be developed for injuries of the back, a clear understanding must be had of the diagnosis aod differential diagnosis of oot only the trauma but all associated conditions which might influence the back disability.

Anatomy of Back.—The onatomy of the back must be thoroughly understood if one is intelligently to treat injuries of the back. A review of the regional anatomy once or twice a year is not too much to ask of the surgeon caring for back conditions. I am opposed to one's becoming simply a "back specialist." There is too great a tendency to interpret all general and local conditions lo terms of back disease or injury. One must be a good general surgeon if he is to meet the many surgical problems presented by back injuries. Again, there are frequently associated injuries in distant parts of the body, in the skull, the extremities, the abdomen (as a ruptured liver or kidney or bladder) requiring general surgical knowledge which cannot be met by the genuine "back specialist."

Spine.—The surgical anatomy of the spine has been written by many excellent anatomists aod clinicians. Rather than repeat the salient features of these articles the following quotation is taken from Fisher's book on *Manipulative Surgery* [3]:

A brief reference to some special points in the surgical anatomy of the spine, and to the normal range of movement possible in the different regions thereof, is an indispensable preliminary to any discussion of the conditions therein which are amenable to manipulation and of the manipulation technic involved. For the general anatomy of this complicated region the reader is referred to the textbooks of anatomy. As, however, the latter but rarely give any reliable information upon the movements of the spine, a brief account will be given, in which we shall follow the admirable observations of Lovett.

The spine is an elastic column, the strength of which depends on the fact that it consists of a number of vertebrae, the degree of movement between individual bones being slight, but the sum of movement is considerable. The arrangement of the spine in a series of curves also gives far greater strength to the spine, for a vertical force is decomposed by the curves. The weakest mechanical point in the spine is where the comparatively rigid dorsal spine meets the more mobile lumbar portion.

The prolonged nature of the disablement following many spinal injuries is not difficult to understand if we bear in mind the extreme complexity of this region, and the multiplicity of the joints, ligaments, and muscles connected therewith. The important fact must never be overlooked that the spinal cord traverses the neural canal of the vertebrae and that important nerves emerge

physiologic curve can be increased slightly, the greater part of the apparent movement occurring at the occipito-atlantal joint.

Lateral Flexion.—As we have seen, this movement is always combined with a certain amount of rotation, but the lateral flexion factor is most marked in the lumbar zone. It is interesting and important to note that when the spine is flexed, lateral flexion occurs at a higher level in this region, and at a lower level when the spine is hyperextended.

Rotation.—In striking contrast to the lateral flexion element, the rotatory element is almost negligible in the lumbar region, but is most marked in the dorsal and cervical region. It is not difficult to understand why this should be so if the reader will glance at the shape of the articular processes in the different zones. Here, again, when the spine is fixed, rotation occurs at a higher level than in the erect position, but when the spine is hyperextended, at a lower level. Thus, by altering the degree of flexion or extension of the spine, the effect of rotation and lateral flexion can be brought to bear on successive spinal regions.

FIG. 1.—Congenital absence of upper left transverse process of sacrum. Weak back for years. Recently suffered slight injury, with marked increase in back pain.

Pathologic Conditions.—The following classification is one adopted by the author for the purpose of depicting the pathologic possibilities in the spine itself as well as those pathologic conditions which are extraneous to the spine but which may cause referred pain in the back:

I. Congenital Defects
   A. Absence of a vertebra or portions of one or more vertebrae (Fig. 1)
      1. Spina bifida occulta

LIGAMENTS.—These are exceedingly numerous, and for their detailed description a textbook of anatomy should be studied. It will be sufficient merely to mention that not only are there ligaments which stretch between the vertebral bodies (anterior and posterior common ligaments and intervertebral discs), but also ligaments which connect the articular processes, laminae, spinous, and transverse processes. Further, there are ligaments connecting the heads of the ribs with the bodies of the vertebrae, and others connecting the necks and tubercles of the ribs with the transverse processes. In the upper cervical and lumbosacral region there are other important ligaments having special functions.

SPINAL SURGICAL LANDMARKS.—A few of the most important and essential of these are given. Five minutes spent in committing them to memory will be amply repaid.

Root of Spine of Scapula: Interval between third and fourth dorsal spines
Inferior Angle of Scapula: Interval between seventh and eighth dorsal spines
Highest Point of Iliac Crest (Interiliac Plane): Fourth lumbar spine
Posterior Superior Iliac Spine: Second sacral spine
Spinal Cord Ends: First lumbar spine (transpyloric plane)
Spinal Theca Ends: Third sacral spine

MOVEMENTS OF THE SPINE.—The actual movements in the spine itself are really less than might at first sight be assumed on observing full forward flexion, for a considerable amount of the apparent movement is pelvic and takes place at the hip joints and some of the movement occurs between the skull and the spine.

If we are desirous of ascertaining the actual movements of the spine itself, some means must be taken of fixing the pelvis, and correction must be made for movement at the occipito-atlantal joint. Similarly, if exercises and passive manipulations are performed which are intended to act upon the spine alone, the pelvis should be fixed.

The actual movements may be divided into flexion, extension, and a complicated movement—lateral flexion rotation. There is no such movement as a pure lateral flexion, for a certain amount of rotation inevitably accompanies this. Similarly, rotation is always accompanied by a certain amount of lateral flexion. It is important to remember, however, that there is a variation in the degree of the rotatory and the lateral flexion elements, respectively, in the various regions of the spine. The nature of the movements is largely influenced by the shape and the direction of articular surfaces.

Flexion (Bending Forward).—This movement is most marked in the lumbar region, and is possible until the normal forward convexity is practically obliterated. The movement is more marked, therefore, in the lower part of the lumbar region. In the cervical region flexion can occur until the physiologic curve is obliterated. Most of the apparent movement of flexion really occurs at the occipito-atlantal joint. In the dorsal region forward movement is very slight, but the normal convexity backward is slightly increased.

Extension (Bending Backward).—This movement is most free in the lumbar and the two lower dorsal vertebrae. Very little movement in this direction occurs in the remainder of the dorsal region, and in the neck the

II. Postural and Acquired Defects
   A. Kyphosis
   B. Scoliosis
   C. Lordosis
   D. Spondylolisthesis
   E. Dorsal round back
   F. Posterior displacement
   G. "If the spinal column is not deviated laterally and its normal lordotic and kyphotic anteroposterior curves are not exaggerated; if the spinal curves which are associated with the habitual posture of the individual are not so extreme as to threaten or produce joint and muscle strain or disturbance of the visceral relations; if the posture is such that there still remains a 'margin of safety' which allows more mobility in all directions, the spinal curves and the weight-bearing lines of the lower extremities may be said to fall within normal limits for the individual under consideration."[3]

III. Diseases of the Back
   A. In the spinal column proper
      1. Osteo-arthritis
         (a) Usually hypertrophic
         (b) Ankylosing arthritis (Strümpell-Marie disease)
         (c) May be destructive type
         (d) Of unknown infectious origin
         (e) Neisserian
         (f) Toxic, traumatic
      2. Synovitis (lateral articulation)
      3. Osteomalacia
      4. Kümmell's disease
      5. Vertebral epiphysitis
      6. Herniation of intervertebral disc
      7. Abscess of disc
      8. Spondylitis
         (a) Tuberculosis
         (b) Osteomyelitis
         (c) Syphilis
         (d) Typhoid spine
         (e) Sporotrichosis, etc.
      9. Tumors
         (a) Usually metastatic carcinoma
         (b) Sarcoma
         (c) Giant-celled tumors
         (d) Hypernephroma
         (e) Hemangioma of vertebral bodies

2. Hemivertebrae
3. Klippel-Feil syndrome (absence of two or more cervical vertebrae)

B. Extra vertebrae
1. Eighth cervical
2. Sixth lumbar
3. Fourth lumbar

C. Faulty angulation of fifth lumbar on sacrum—a congenital spondylolisthesis

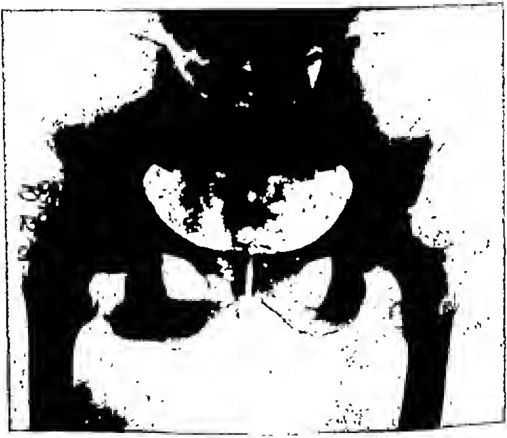

FIG. 2.—Sacralized 5th lumbar vertebra on left side.

D. Sacralized fifth lumbar (Fig. 2)
E. Elongated fifth transverse process definitely impinging upon or articulating with the sacrum or ilium
F. Cervical ribs
G. Malpositions of the coccyx
H. Separate neural arch
I. The slender individual with almost a straight spinal column, the long-waisted type, seen most frequently in the neurotic or in subjects prone to develop functional disorders

3. Contusion of the cord
4. Hemorrhage into the cord
5. Tearing of the nerve roots
   (a) Brachial plexus evulsion
   (b) Cauda equina lesions

C. Surrounding the spinal column—Soft tissue injuries
   1. Strains—traumatic lumbago or myofascitis

Fig. 32.—Fracture of 1st cervical vertebra—lateral view.

B. Within the spinal canal
   1. Spinal meningitis
   2. Spinal syphilis
   3. Tabes dorsalis
   4. Syringomyelia
   5. Multiple sclerosis
   6. Cord tumors
   7. Poliomyelitis and myelitis
   8. Cord changes due to pernicious anemia
   9. Extradural abscess
   10. Myeloma
   11. Vertebral artery aneurysm

C. Surrounding the spinal column
   1. Muscular rheumatism, myositis, myofascitis (lumbago)
   2. Psoas abscess or mediastinal abscess
   3. Boils, carbuncles, or abscesses with scar tissue formation
   4. Osteomyelitis or tuberculosis of sacro-iliac joint
   5. Tumors of soft tissues of back
      (a) Lipomas
      (b) Pilonidal cysts
      (c) Malignant tumors
   6. Progressive muscular atrophy
   7. Neuritis
      (a) Herpes zoster
   8. Bursitis

IV. INJURIES OF THE BACK

A. In the spinal column proper
   1. Fractures of body or lamina
   2. Dislocations
   3. Fracture-dislocations (Figs. 3a, 3b)
   4. Fracture of spinous or transverse process
   5. Dislocation at vertebral costal joint
   6. Inpingement of eleventh and twelfth ribs
   7. Impingement of spinous process
   8. Sprains
      (a) Sprain-fracture at tip of transverse process
      (b) Associated with partial displacements or rotations
      (c) Tearing off of osteo-arthritic spur
   9. Partial displacements
      (a) The atlas upon the axis
      (b) Lumbosacral

B. Within the spinal canal
   1. Compression of the cord
   2. Laceration of the cord

D. Sacro-Iliac
  (a) Strains
  (b) Sprains
  (c) Partial dislocation
  (d) Complete dislocation
  (e) Traumatic arthritis
  (f) Associated with fractures in the pelvic girdle

E. Coccyx
  (a) Fractures
  (b) Dislocations
  (c) Contusions

V. Possible Types of Associated Injuries with Traumatic Back

A. Head
  1. Skull fracture
  2. Cerebral injuries

B. Chest
  1. Fractured ribs
  2. Penetrating wound of lung
  3. Pleuritis
  4. Injuries of scapula

C. Abdomen
  1. Rupture of mesentery
  2. Rupture of liver
  3. Rupture of spleen
  4. Rupture of kidney
  5. Rupture of stomach or intestine
  6. Contusions of one or more of these viscera
  7. Rare injuries to gallbladder or pancreas

D. Pelvis
  1. Fracture of pelvis
  2. Rupture of bladder
  3. Rupture of ureter
  4. Contusion of urethra
  5. Bladder and rectal disturbances
  6. Rare injuries to pelvic viscera

E. Extremities
  1. Brachial plexus irritation, paresis, or paralysis
  2. Sciatica
  3. Paresis or paralysis
  4. Fractures in one or more extremities

VI. Other Diseases Which May Cause Painful or Pathologic Backs

A. Focal infections
  1. Tonsils

2. Sprains—tearing of ligaments
3. Adhesions about the joints or in the lumbar aponeurosis
4. Muscle changes
   (a) Tearing of muscles
   (b) Fibrositic deposits
5. Peripheral nerve injuries near exit from spinal column
6. Traumatic wryneck
7. Contusions
8. Hematoma
9. Burns
   (a) Scar contractures
10. Foreign bodies
11. Penetrating and lacerating wounds
12. Lumbar hernia

Fig 3b.—Anteroposterior view shows slight lateral dislocation.

C. The injury may aggravate existing disease
   1. Osteo-arthritis of spine
   2. Myofascitis
   3. Tuberculosis of spine
   4. Aggravating a preëxisting deformity
      (a) As in an old infantile paralysis

It is evident from the above outline of the more common pathology involved in this question that the diagnosis and the differential diagnosis of back injuries and back disease furnish some of the most complicated problems found in medicine.

Diagnosis.—The gross lesions of the back following trauma, such as a definite compression fracture or a dislocated vertebra, are not difficult to diagnose provided proper attention is paid to the history of the injury and to the complaints of the patient, and suitable x-ray pictures are taken. Even in these conditions a thorough general examination is necessary to discover associated injuries or signs of associated disease, postural defects, or infectious conditions which may aggravate the injury and be of great importance in the prognosis.

Since Davis (Vol. II) deals with spinal cord injuries which usually follow fractures or dislocations of vertebrae, conditions of this type will not be considered in this chapter.

The less serious back traumas are far more difficult to diagnose. So many associated conditions, both in the spinal cord and in the general systemic examination, have a potential influence that it requires the greatest ingenuity on the part of the examiner to differentiate between these and the alleged trauma.

History.—The history of the case is of the greatest importance in diagnosing these back injuries. If the patient is brought into the hospital following a major accident, for example, after a head-on collision between two automobiles, the history develops potentialities for all kinds of major and minor injuries to the individual. Here a careful physical examination is made of the head, neck, chest, abdomen, back, pelvis, and extremities, and often a catheterized specimen of urine is obtained to ascertain the condition of the kidneys, bladder, and urethra. The x-ray is brought in as a diagnostic aid *as soon as the condition of the patient warrants.* The injury to the vertebra is discovered either as the sole injury or as associated with a skull fracture, fractured ribs, a fractured pelvis, or other injuries.

However, in those disabling back conditions which fail to show definite x-ray pathology or which develop several days after the alleged injury, the history assumes greater importance. How severe was the injury? When was it received? Was the injury due to a direct or an indirect force? Has the patient been subject to backache? Have there been previous injuries to the back, and if so, what was their nature.

2. Teeth
3. Sinus infections
4. Acute or chronic infections anywhere in the body

B. Aneurysm or tumors
1. In chest
2. In abdomen
3. In pelvis

C. Abdominal conditions
1. Gallbladder disease
(a) Referred pain during gallstone colic
(b) Constant back pain may be only sign of gallstones
2. Appendicitis—especially retrocecal appendix
3. Ulcer of stomach
4. Colitis, especially spastic constipation
5. Diverticulitis, especially of sigmoid
6. Hernia

D. Kidney conditions
1. Perinephritic abscess
2. Kidney or ureteral stone
3. Twisting of pedicle of kidney—Dietl's crisis

E. Retroperitoneal conditions
1. Tumors
2. Enlarged glands

F. Pelvic conditions
1. Displacements of uterus occasionally
2. Tumors of uterus
3. Infections of adnexa
4. Cysts of ovary—twisted pedicles
5. Prostatic disease
(a) Inflammatory
(b) Tumors

VII. Any of the Above Diseases May Exist at the Time of a Given Injury to the Back

A. The injury may be only coincidental, neither aggravating nor contributing to the disease
1. As in metastatic carcinoma of spine
2. As in gallstones
3. As in tumor of abdomen or of prostate

B. The injury may be a contributing factor
1. As in osteomyelitis of spine
2. As in twisted pedicle of ovarian cyst
3. As in acute gallstone colic developing shortly after injury
4. As in acute retrodisplacement of uterus coming on immediately after injury and persisting until relieved by manual replacement

into varied types of traumatic neuroses. It is sometimes extremely difficult to distinguish between the true organic and the functional condition or properly to evaluate each when there is a mixture of both in the same case.

X-RAY.—The x-ray is invaluable in the diagnosis of back injuries. It is too often neglected in cases resulting from rather minor accidents or is not resorted to until weeks or months later. The late x-ray may show osteo-arthritic changes or other findings, and because of the failure to take the earlier x-ray, one is unable to say definitely that this or that condition was preëxistent and that it has no relationship to the alleged injury.

FIG. 42.—Anteroposterior view of the spine made at time of injury in Michigan. Diagnosed as negative for fracture.

and when? What was the position of the patient when injured—sitting, standing, bending over, or erect? Has he had recent toothache or tonsillitis or have teeth been pulled or the tonsils removed recently? Has he been subject to colds or sinus trouble? What is the condition of the bowels? Has appendicitis been diagnosed or an appendectomy performed? Has he been jaundiced? In the case of a woman, have there been any pelvic complaints? In the case of a man, is there a history of urinary or prostatic trouble? Has there been any marked loss or decided gain in weight recently? Has there been any foot trouble or pains in the calves of the legs or thighs? What is the exact nature of his or her work? Has there been any recent change from sedentary to heavy occupation? What have been the past illnesses? What is the family history?

These and every other possibility which might throw light upon the alleged back disability must be delved into in the history.

Physical Findings.—The complete physical examination is of equal or usually greater importance. If the case is one from a major accident, the examination starts with the head and includes every part of the body that might have been injured, followed by a careful routine examination as soon as the condition of the patient permits. If the patient complains of back disability from an alleged trauma, the injured part is first examined and this is followed by a painstaking complete, general examination. Each physician should develop a fixed routine for this or any other examination in order not to overlook any part.

If the patient is in bed, it may be difficult to turn him over for an examination of his back, but this should be done, if at all possible, care being taken to avoid undue pain of movement or the danger of increasing his trauma. If the case is ambulatory, the examination is best started with the patient sitting on a stool. Later he should stand and, finally, he should be in the prone position on the examining table.

Close but unobtrusive observation of the patient should be made during the taking of the history, while he is undressing, and during the examination. Often data will be obtained in this way which will be invaluable in arriving at a true diagnosis.

In the case of a severe trauma to the spine, for example, a compression fracture, one seldom encounters signs or symptoms of neurosis if it has been properly treated. On the other hand, the signs and symptoms in some of these less severe back injuries are so obscure or so difficult for the patient to express, or give such atypical complaints that there is too often a tendency on the part of the physician to classify the case as one of traumatic neurosis. Unquestionably many back injuries, due to failure to receive relief after many changes in physicians and in the lines of treatment, or due to inherent fears of a "broken back," or due to a desire for compensation for their suffering, abetted frequently by overzealous relatives or lawyers, do develop

x-ray, both views being taken within two to four weeks and still another being made within a few weeks thereafter, if necessary. Too often the compression fracture will not show on the first films but the compression gradually occurs due to movement or weight-bearing, and the later film reveals the true condition. In the case of persistent trouble, the second, third, or even the fourth film will be the only means of diagnosing the traumatic arthritis or the secondary tumor that, rather than some minor injury which was coincidental, most probably was the original cause of the back pain.

The following case reports illustrate these points concerning x-ray examination:

CASE 1.—Dr. T., aged 52, attended a medical meeting. When he sat down, the chair slid from under him. As he fell forcibly to the floor, the back of the chair struck him in the mid-dorsal region. He was immediately in excruciating pain and was carried to a couch in the anteroom. As soon as the essayist, a noted surgeon, was through, he went to the injured doctor, examined him through his shirt, felt a swelling over his mid-dorsal spine, and advised that he be taken to the essayist's hospital at once for what was most probably a subluxation of a dorsal vertebra. The patient was moved to this hospital and early the next morning x-ray pictures—both views—were made of his spine. An hour later the surgeon and the roentgenologist came to the patient's room, bringing the x-rays with them, and told him that nothing was broken or dislocated in his spine and that he would be all right after a few days' rest. No further examination was made by this surgeon. The doctor suffered severely and required morphine for four or five days. He had a special nurse who rubbed his back but otherwise no treatment was given. At the end of a week the patient called an excellent internist. He examined the patient thoroughly and also examined the x-rays. His findings revealed almost complete absence of breath tones in the left chest, tenderness over the mid-dorsal vertebrae, a spasm of the muscles on attempted deep breathing, and an extremely nervous individual. During the second week the surgeon began to plague the doctor about being a "neuro" and the latter sensed this to be the feeling of most of the hospital staff. Therefore, on the advice of the internist, he left the hospital on the fifteenth day, going to his home. On the sixteenth day, fearing that perhaps he was a "neuro," this doctor got up and dressed and went to his office in a taxicab. He could hardly stand the jolts of this ride and after a few hours in his office he collapsed. The pain was extreme and he could hardly breathe. He was taken home and the internist was called, who again found a spasm of the back and chest muscles on the least effort at deep breathing. He advised the doctor to remain in bed. The internist again visited the hospital and examined the old x-rays but could find no sign of injury to the vertebrae. The doctor remained in bed for a month, although after a week he could be helped to the toilet. By the end of the month the internist agreed with the original surgeon that this was a case of neurosis. His opinion was strengthened by the fact that the doctor planned a lawsuit against the hotel where the meeting was held, holding a defective chair responsible for his injuries.

After another month the internist asked the author to see this doctor, stating that while he was a "neuro," yet he might have some injury to his back.

Always x-ray the spine at the site of the alleged injury when the patient first presents himself. If the site of the injury is not definitely localized, x-ray well above and below the injured part. In many cases it is safer to x-ray the entire spine.

It is still necessary to emphasize and reëmphasize to the profession the importance of taking *both* an *anteroposterior and a lateral view of every spine requiring* an *x-ray, no matter whether for an injury or for a suspected disease.* Hardly a month goes by that I do not see one or more patients with a definite vertebral injury who has been in the

FIG 4b—Same case with lateral view made three weeks later showing marked compression fracture of 12th dorsal vertebra.

hands of some other physician and who has had an x-ray examination; yet, when he is x-rayed at our hospital, the lateral views show a compression fracture. Asking for and examining the first x-ray films, we find that only an anteroposterior view had been made. This failure to take the lateral view accounts for far too many failures in diagnosis and far too many cases of prolonged back disability due to inadequate treatment (Figs. 4a, 4b).

Again, if the first x-ray picture is negative and yet the signs and symptoms of injury persist, one should always resort to a second

The doctor was rather difficult to treat but gradually recovered from his pain and discomfort under rest, heat, massage, and a body corset.

This case illustrates the failure to secure a complete history or to give sufficient weight to certain facts in the history; the failure of the original surgeon to examine the patient thoroughly; the failure to take a second x-ray when the signs and symptoms persisted; and finally, the failure to treat the case adequately because of failure properly to

FIG. 5b.—Lateral view of 2nd x-ray of same case taken four months later showing a marked compression fracture of 8th dorsal vertebra.

It took three-quarters of an hour to secure a complete history from the patient. Examination showed a definite knuckle deformity over the eighth dorsal vertebra. He had several variable tender vertebrae, but the tenderness was always constant and marked on pressing over this eighth dorsal. At the writer's suggestion he was taken to St. Luke's hospital the next morning for an x-ray and possible treatment.

The x-ray examination the next day showed in both views a very marked compression fracture of the eighth dorsal vertebra (Figs. 5a, 5b). Later I examined the original x-rays and agreed that they failed to show this fracture.

FIG 5a.—Lateral view of first x-ray taken the day following the injury and showing no fracture

The doctor was rather difficult to treat but gradually recovered from his pain and discomfort under rest, heat, massage, and a body corset.

This case illustrates the failure to secure a complete history or to give sufficient weight to certain facts in the history; the failure of the original surgeon to examine the patient thoroughly; the failure to take a second x-ray when the signs and symptoms persisted; and finally, the failure to treat the case adequately because of failure properly to

FIG. 3b—Lateral view of 2nd x-ray of same case taken four months later showing a marked compression fracture of 8th dorsal vertebra.

It took three-quarters of an hour to secure a complete history from the patient. Examination showed a definite knuckle deformity over the eighth dorsal vertebra. He had several variable tender vertebrae, but the tenderness was always constant and marked on pressing over this eighth dorsal. At the writer's suggestion he was taken to St. Luke's hospital the next morning for an x-ray and possible treatment.

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FIG. 5a.—Lateral view of first x-ray taken the day following the injury and showing no fracture.

Traumatic Lumbago, Myofascitis.—The differential diagnosis between the traumatic back and certain diseased conditions is not always easy but is of prime importance both in prescribing treatment and in those cases of a medicolegal character where the honest opinion of the surgeon is necessary in deciding between liability and non-liability, compensation and noncompensation.

In the case of a slight injury followed by a painful low back, the question as to whether this is a "rheumatic lumbago" or a "traumatic

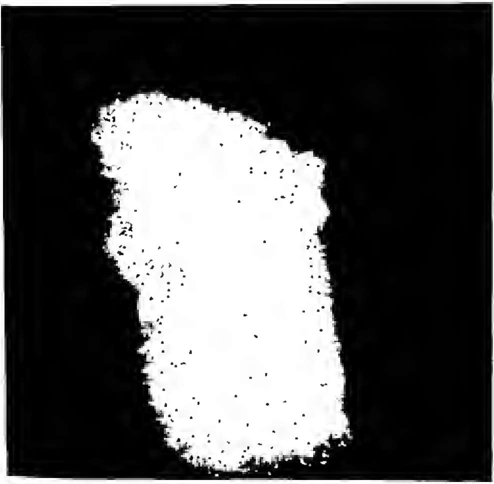

Fig. 6.—Lateral view of spine in case of Mr. B. showing compression fracture of first and third lumbar vertebrae.

lumbago" is answered with difficulty. Muscular rheumatism or a myofascitis very frequently attacks the erector spinae muscles. If the patient states that he was lifting when the attack suddenly started, or that he was carrying a heavy desk with a fellow employee who dropped his end of the desk, throwing all the weight of the desk upon the patient, or that he slipped upon some grease while walking through

diagnose the condition. The mistake of calling him a "neuro" is the usual mistake when all these failures are present.

CASE 2.—Mrs. M., aged 40, married, sustained a fall of little consequence in March, 1929. Approximately two weeks later she complained of pain in her lower back. A good surgeon was consulted and after obtaining this history of falling and after examining her and finding pain and tenderness near the left sacro-iliac region, he had an x-ray picture made. This was negative. The diagnosis of sacro-iliac sprain was made and the patient was treated with heat, massage, and strapping. The pain persisted and finally, after five months of treatment without relief, the surgeon made another x-ray examination. This film showed a marked metastatic carcinoma of the left ilium, near the sacro-iliac joint.

Together with the surgeon, I saw this patient and helped to explain to the husband that his wife had a hopeless, incurable condition and tried to make him understand why it showed in the second x-ray when it did not show in the first one. Of course, the condition could have been discovered earlier by the principle laid down above, viz.—*If a condition persists and the first x-rays were negative, repeat the x-ray within four weeks and repeat again in a few weeks, if necessary.*

CASE 3.—Mr. B., aged 60, an engineer, fell from his engine and struck his back across a rail. He was carried to his home and the doctor was called. Examination was negative, but the doctor suggested that if the patient was still in pain the next morning, he would take him to the hospital for an x-ray. The next morning, however, the patient was better and no x-ray was taken then or at a later date. After a week this patient got out of bed and limped around the house and yard but always complained of pain in his spine when he tried to get up from bed or from a chair and again when he tried to sit down. After six months he was sent to me for an examination, with the statement from his doctor that the old man was making too much out of his injury and wanted to get a pension.

The history was important, namely, the fall across the rail. The patient acted perfectly natural and showed none of the earmarks of exaggerating his complaints. The examination showed a definite spasm of the muscles in the lumbar region when he attempted to rise from the sitting position. Palpation over the vertebrae showed no variable points of tenderness but always a constant point of tenderness over the third lumbar vertebrae. The x-ray examination confirmed my diagnosis of compression fracture of the third lumbar vertebra. There was also a compression fracture of the first lumbar. These fractures, however, did not show upon the anteroposterior view and without the lateral view would have been missed (Fig. 6).

The failure to take an x-ray here resulted in a wrong diagnosis and later to the patient's being called a "neuro" or exaggerator.

Differential Diagnosis.—One must be alert to discover diseased conditions of the spine which simulate, in their early stages at least, the traumatic back.

Examination showed an old man who was definitely suffering pain. The back examination was negative except for some limitation of motion that could easily be due to osteo-arthritis, and for a definite, constant point of tenderness in the region of the fourth lumbar vertebra. The rectal examination revealed an enlarged, indurated prostate that was undoubtedly malignant.

X-ray examination showed a destructive process in the body of the fourth lumbar vertebra.

Diagnosis was readily made of primary carcinoma of the prostate with a secondary growth in the vertebra.

The complete physical examination, including the rectal examination, combined with the later follow-up x-ray examination, made it possible to differentiate this from an accidental or traumatic condition. It likewise saved the village of R—— a considerable sum of money when suit was brought to collect damages for the alleged accident.

Disproving Alleged Stiffness.—I have mentioned the importance of unobtrusively observing a patient carefully during the examination. Occasionally a patient will complain of stiffness in the back and during the examination will show definite limitation of flexion movement. When the examination is completed, see that the patient's clothes are lying on the floor. Tell him to dress and then apparently leave the examining room or otherwise seem to pay no attention to the patient. Occasionally such a patient will lean over and pick up his clothes, showing that now that the examination is over his back is not nearly so stiff as it was during the examination.

One of my favorite ways of disproving an alleged stiffness in the back is the following: I slip on a glove and tell patient that I want to make a rectal examination. The patient is placed in front of a low table or chair; finger is inserted in the rectum and of course it is painful; patient is told to lean over the table or chair and it will not be so painful. The examination is kept up until the patient has flexed his back equal to any normal flexion. These and many other methods can be adopted to prove the neurosis or malingering cases.

Diagnosis has been considered at length before taking up the problems of treatment because of the surprisingly large number of these back injuries which receive various lines of treatment although no definite diagnosis of the real condition has been made. I have seen many patients who should have been in bed at absolute rest, going daily to a doctor's office for physical therapy treatment, namely, quartz light treatment, or more often, diathermy, or in some instances, baking and massage. Some of these patients have had compression fractures undiagnosed. Other patients with trivial injuries have been kept in bed for weeks, or fitted with a Taylor belt or given physical therapy treatments, usually light or diathermy, and have developed true neuroses chiefly because of overtreatment. Therefore one *cannot* write concerning the traumatic back without emphasizing the importance of diagnosis. The two must go hand in hand.

the factory; if there were witnesses to this slight accident; and finally, if the examination reveals a definitely lame back, then it is practically impossible to disprove the injury element. Even if there is a past history of lumbago and the findings are definitely those of lumbago, the slight accident can be held to be an aggravation of an existing condition. On the other hand, if the patient gets a sudden attack of lumbago when arising from bed or upon turning over in bed, or following a Saturday afternoon of helping his wife clean house, then the question of accident seldom arises and the case is clearly one of "rheumatic lumbago." As a rule, both conditions are exactly the same. In these indefinite back conditions the question of injury would not be raised so often if an accident insurance policy or an employer's liability law was not involved.

Posture, Body Mechanics, Flatfoot.—In all cases of back injury or backache, especially in the low back pain, the surgeon must search for faulty posture, poor bodily mechanics, and such defects as flatfoot. A third degree flatfoot is very frequently the active etiologic factor in the alleged traumatic back, the slight injury being only the exciting or contributing cause. Months of prolonged treatment in such cases may be avoided by discovering and stressing the treatment of the flatfoot condition.

Tuberculous Spondylitis.—This may be the cause of the pain and disability for which some trivial injury is held responsible. The appearance of a psoas abscess may be the first indication which the patient develops to show the true condition.

Kümmell's Disease.—Kümmell's disease, or the development of a traumatic spondylitis months after the injury, must be differentiated from the tuberculous spondylitis and from the osteoporotic type of arthritis.

In those regions still subjected to typhoid epidemics the "typhoid spine" must likewise be considered in a differential diagnosis.

Metastatic Malignancy.—This has already been mentioned. The spine is a very frequent site for these metastatic malignancies. Early the x-ray may be negative, but one must persist in the x-ray studies of the spine whenever the possibility of this condition is known to exist or can be suspected.

Case 4.—M. T., 63 years old, slipped on the ice while working for the village of R——. He completed his day's work but the next day had pain in his back and therefore went to the village physician. An x-ray was taken but was negative. His back was strapped. Pain persisted but he was able to work off and on for a few weeks and then was forced to quit. About two months following this alleged accident he was referred to me for examination and opinion as to whether it was a traumatic back, and for suggestions as to treatment.

If you have no physical therapy department, get one. Do not refer your cases to nonmedical physical therapists or to unsupervised technicians, or to the club gymnasium or to similar places where you lose the essential control of the patient and the more essential continued interest in his recovery.

Spinal Fractures with Cord Injury

Fractures should be divided into those cases having signs and symptoms of cord injury and those without cord injury.

Davis (Vol. II) deals with fractures involving the cord, and, therefore, these will not be considered here. However, one cannot refrain from pointing out the importance of using physical therapy methods in such cases. Many of these cases seem hopeless, even after an early laminectomy. Nevertheless, a certain percentage of the hopeless cases do recover. Nothing is more pitiful than to see a patient with a fractured back accompanied by paralysis gradually regaining some power in his legs and yet unable to walk, even with crutches, because his feet have been allowed to ankylose in an extreme equinus position.

Treatment.—A laminectomy is important, but the after-treatment of these cases is equally, if not more, important. Within the first 48 hours some method of protecting the feet from the disabling foot-drop position is essential. One can use sand bags or, better, a padded splint fitted to each foot with an elastic extending from the top of the splint to the leg just below the knee where it is attached by a small piece of tape.

Within the first week, light stroking massage of the extremity, from the foot to the hip, should start. This should never be a heavy massage, lest one injure the blood vessels now so poorly protected by the paralyzed muscles. As time goes on, the firmness of the massage may increase. This can be judged by the tone of the muscles.

Muscle-training exercises, similar to those described in the chapter on infantile paralysis (Legg, Vol. II) and in the chapter on brain and spinal cord lesions (Davis, Vol. II), should start not later than the second week and should be persisted in for months or until the patient can begin to exercise and train his own muscles. When this stage is reached, occupational therapy planned for a definite purpose will be helpful in improving function. The swimming and underwater exercises so well described by Lowman (Vol. III) can be utilized in these cases to great advantage.

The following two cases will emphasize the above points:

Case 5.—M. T., aged 40, suffered a compression fracture of the first lumbar vertebra with immediate paralysis of both lower extremities. A laminectomy was performed. The patient then lay in bed for eight months, when he was transferred to a wheel chair. At the end of a year and a half, he entered the surgical service at St. Luke's hospital, under the care

Physical Therapy Axioms for Back Treatment

Given a trivial injury in a nervous individual who shows a tendency to exaggerate his condition, one can often rub in more disabling conditions in a week than be can rub out in a year.

In such an individual, as well as in other neurotic types, one can employ diathermy, quartz lights, infra-red bakers, and similar apparatus to the extent of impressing him with the seriousness of the situation and thereby aggravating the neurosis.

The fitting of a back brace or a sacro-iliac belt is occasionally indicated in certain cases, but in many others such a procedure is equivalent to dooming the patient to a life of invalidism.

It is often more difficult to get patients who have recovered from back injuries to give up their back braces than it is to get some old fractured cases to give up their crutches.

If a patient is a compensation case, the back brace often is the etiologic factor in a compensation neurosis. The "railway spines" of yesterday have been replaced by the "traumatic neuroses" of today. Given an ambulance-chasing lawyer and his medical cohort who fits such a case with a cumbersome back brace and you have a combination hard to beat.

The spine is made up of numerous joints which are adjacent to the two large sacro-iliac joints. Immobilize these joints for any length of time and stiffness is bound to follow. Massage and exercise are the two best means of combating ankylosis here as well as in other joints.

He who treats back injuries must know or have access to intelligent physical therapy.

Machine therapy alone is not intelligent physical therapy. You can turn a "light" on these old back cases from now until doomsday without any effect.

If desirable, use a light or diathermy machine to heat the part but follow this with massage, muscle-training exercises, and graduated doses of work if you want a cure.

Physical therapy in 90 per cent of the cases consists of equal parts of trained hand work and of ability to get the patient to help himself. In the other 10 per cent of the cases it may be necessary to combine with these some form of machine therapy.

Common sense and judgment are essential qualifications in using or prescribing physical therapy.

"A little knowledge is a dangerous thing" is especially applicable to a technician. A talkative technician or one wedded to a given *modus operandi* may drop a remark, make a suggestion, refuse to coöperate because her method is better, or otherwise sow seeds of doubt, fear, or dissension in the patient's mind to the extent of nullifying the benefits of the physical therapy treatment.

A trained technician may administer, but the surgeon must supervise the physical therapy treatment.

of Dr. Holmblad. The patient could move his legs, but the lower extremities were entirely and markedly atrophied. The knees could be flexed with slight assistance. The feet, however, were clawlike and were fixed in an exaggerated equinus position. If the patient was held in an upright position, his weight rested directly on the tips of his toes. Dr. Holmblad fitted leg and thigh braces on this patient with a caliper arrangement which held the feet just off the floor when the patient rested his weight on the base of the calipers. Daily massage, muscle-training exercises, and lessons in walking with the aid of crutches and the braces comprised the plan of treatment. The patient improved in strength but will probably never be able to do without his braces and walking calipers. This is the picture of the patient who received good surgical treatment as far as the laminectomy was concerned, but extremely poor or no surgical after-care (Fig. 7).

CASE 6.—On visiting a hospital in a nearby city I was invited by the surgeon to inspect the ward cases. He showed me a male patient 50 years of age who had suffered a fractured vertebra with cord compression some 11 months previously. A laminectomy had been performed. The patient was in good condition but the paralysis of the lower extremities was still complete. A marked foot drop was present and it was impossible to dorsiflex his feet manually. This patient, even though he should recover, would be doomed to be a bed or wheel-chair invalid the rest of his life. This surgeon stated that he did not take much stock in physical therapy.

RECENT TRAUMA OF SPINE WITHOUT CORD INJURY

Recent injuries of the spine without cord lesions can be divided into: (a) compression fractures of the body; (b) fractures of the transverse processes; (c) fractures of the laminae and arches; (d) fractures of the spinous processes; (e) dislocations and subluxations; (f) fracture-dislocations; (g) sprains, strains, vertebral locking, etc.

COMPRESSION FRACTURES

Compression fracture of one vertebral body is the commonest type. It may be accompanied by similar fractures in other vertebrae or by associated fractures, such as fractures of one or more transverse processes. The usual mechanism is a forcible flexion of the spine, causing a crushing of the anterior portion of the body. At times there is a forward displacement of a small wedge of the body of the vertebra.

The immediate surgical treatment of this condition varies from absolute recumbency to operative fixation by bone transplantation across the site of the fracture. Between these two extremes many methods of repair are recommended.

Personally, I have seen very few compression fractures of the spine in which I felt that either an Albee or a Hibbs operation or any other type of bony fixation was indicated. Dixon, of Kansas City, recently advocated, in a clinical meeting, more operations early in these cases, claiming that better end-results followed in his operative cases than

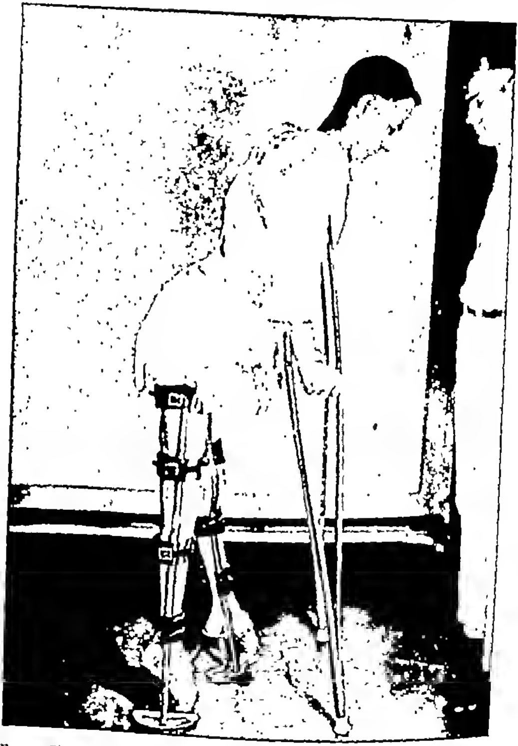

FIG. 7.—Photograph of M. T. (Case 5) who had good surgical treatment of his cord injury but no protection against foot drop.

of Dr. Holmblad. The patient could move his legs, but the lower extremities were entirely and markedly atrophied. The knees could be flexed with slight assistance. The feet, however, were clawlike and were fixed in an exaggerated equinus position. If the patient was held in an upright position, his weight rested directly on the tips of his toes. Dr. Holmblad fitted leg and thigh braces on this patient with a caliper arrangement which held the feet just off the floor when the patient rested his weight on the base of the calipers. Daily massage, muscle-training exercises, and lessons in walking with the aid of crutches and the braces comprised the plan of treatment. The patient improved in strength but will probably never be able to do without his braces and walking calipers. This is the picture of the patient who received good surgical treatment as far as the laminectomy was concerned, bnt extremely poor or no surgical after-care (Fig. 7).

CASE 6.—On visiting a hospital in a nearby city I was invited by the surgeon to inspect the ward cases. He showed me a male patient 50 years of age who had suffered a fractured vertebra with cord compression some 11 months previously. A laminectomy had been performed. The patient was in good condition but the paralysis of the lower extremities was still complete. A marked foot drop was present and it was impossible to dorsiflex his feet manually. This patient, even though he should recover, would be doomed to be a bed or wheel-chair invalid the rest of his life. This surgeon stated that he did not take much stock in physical therapy.

RECENT TRAUMA OF SPINE WITHOUT CORD INJURY

Recent injuries of the spine without cord lesions can be divided into: (a) compression fractures of the body; (b) fractures of the transverse processes; (c) fractures of the laminae and arches; (d) fractures of the spinous processes; (e) dislocations and subluxations; (f) fracture-dislocations; (g) sprains, strains, vertebral locking, etc.

COMPRESSION FRACTURES

Compression fracture of one vertebral body is the commonest type. It may be accompanied by similar fractures in other vertebrae or by associated fractures, such as fractures of one or more transverse processes. The usual mechanism is a forcible flexion of the spine, causing a crushing of the anterior portion of the body. At times there is a forward displacement of a small wedge of the body of the vertebra.

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in those treated by closed methods. Chandler, of Chicago, has recently published an article odvocating a bone transplant or a Hibbs operation in certain obscure fractures of the lamina.[4] He claims that many cases of persistent back pain are due to these fractures of the lamina which are extremely difficult to demonstrate by x-ray and are, therefore, frequently overlooked. Other excellent surgeons have strongly advocated open operations. The preponderance of opinion still favors the more conservative, closed method of treatment.

Treatment.—The priociples of treatment governing these compressioo fractures are:

(o) Correctioo of the deformity by hyperextensioo of the spine
(b) Immobilization: by recumbeocy in bed with some device to maintain the hyperextension; in a body cast, with recumbency; rest in bed and traction; a body cast that allows the patient to be ambulatory; or o specially built back brace
(c) Immobilization aod rest for a variable period, ranging from eight weeks to six months

Walsh's Method.—Walsh, of Pittsburgh, has long advocated the hyperextension treatment of these vertebral fractures and has developed a special bed which can be raised in the middle, thus giving a positioo of hyperextension to the recumbent patient. Davis, of Erie, has developed a procedure which he claims will overcome the compression deformity of the vertebra and restore its body to oormal alignment. This method consists of placing a sling about the feet, with a rope or strap passing from the sling through a pulley in the ceiling; the anesthetized patient lies face downward, and as his feet and legs are raised in the air, his weight rests upon the upper chest. Manipulations of the spine are made with the patient in this hyperextended position. A plaster bed is then applied directly to the patient while he is still in this position. Later this cast can be bisected and the back half removed to permit massage.

Jones' Method.—R. Watson Jones,[5] of Liverpool, describes a simple method of securing hyperextension and of immobilization of the fracture, as follows:

> Not only is a general anesthetic quite unnecessary, but the position required can be maintained much more easily by a conscious than by an anesthetized patient. Although complaint is made of aching and discomfort in the arms where the weight of the trunk is borne, none of the patients complain of pain in the back, so that we have not thought it necessary to adopt Bohler's suggestion of injecting novocaine locally. One-quarter or one-third of a grain of morphine is given half an hour before.
>
> Two tables are arranged end to end, with a space between slightly greater than the length of the patient's trunk. The front table is raised on blocks or chairs so that it is about two feet higher than the other; although not

essential, it is an advantage to use an operating table of adjustable height, so that the hyperextension can be attained gradually by screwing up the table after the patient is in position. Throughout the treatment, flexion of the spine must be avoided. The patient is therefore lifted *face downward* on to the lower table, and a double layer of stockinette pulled over the trunk and stitched over the shoulders and beneath the perineum. The spinous processes and the iliac crests may be further protected by small pads of adhesive felt, but it is essential that the plaster should fit very closely; bulky padding with wool or felt is to be avoided. A closely fitting woolen bathing costume is an excellent substitute.

The patient is now assisted into such a position that he is gripping the edge of the higher table with his abducted arms, the head resting on a small

FIG. 8a.—Example of Jones' reduction of compression fracture of spine.

pillow. The lower table supports his lower limbs as high as the upper thigh, but between the groins and the neck there is no support. In this position he is unable to prevent his spine from gently sagging into full hyperextension (Fig. 8a). The plaster is applied at once, and is well moulded to the curve of the spine, the sacrum, and iliac crests. The rubbing in of layer after layer of plaster gives just sufficient pressure to insure that the normal limit of hyperextension has been reached; beyond this no manipulation of any sort is employed. The plaster should extend up to the neck, and although it may be cut out below each axilla to allow free arm movement, none must be removed from the front of the thorax (Fig. 8b). It extends well over the sacrum and down to the level of the trochanters and symphysis pubis, with a small area cut out over each groin to allow flexion of the hips. If the plaster cast is a good, closely fitting one, it is not necessary, even in lumbar fractures, to

include either hip, and we strongly deprecate the suggestion that these patients should remain recumbent in a plaster bed or frame.

As soon as the plaster is dry, the patient is encouraged to move about in bed and is turned frequently to avoid pulmonary congestion. Wasting and hypotonicity of the spinal musculature must be avoided. From the second or third day in uncomplicated cases definite exercises for the erector spinae are practiced at regular intervals. The patient should lie prone and lift the head from the bed against resistance. Each lower limb should be lifted with the knee straight by hyperextending the hip. These exercises involve energetic contraction of the erector spinae, and despite the plaster jacket a patient can maintain a better muscular tone in this way than he could if any amount of massage and electrical treatment were possible.

After 10 days the patient may get up and walk for increasing intervals. We regard this as a very necessary part of the treatment, not only because it still further assists in maintaining muscular tone and establishes the free circulation which is essential for rapid union, but because it restores the patient's mentality to normal. The sooner a man is dispossessed of the notion that "his back is broken" and that he "will never walk again," the more certainly is subsequent functional disturbance avoided.

Protection of the vertebrae is necessary for four months. If exercises are being constantly practiced, the plaster should be retained for the whole of this time. After 16 weeks, movements of the spine itself are practiced and, if a normal musculature and a normal circulation have been maintained, there will be no difficulty in restoring full movement. Manipulation to break down intermuscular adhesions will not, as a rule, be necessary. Within six months the patient should be capable of resuming his normal occupation.

While as yet I have not had the opportunity of trying this method, it sounds simple, safe, and very rational.

Hempel's Method.—Other authors have described methods of treatment which combine exercise and massage with the active treatment of the fracture. Hempel,* for instance, believes that he has found a way of overcoming the objections against other methods of treatment hitherto employed. When there is no injury of the spinal cord, the patient is laid on a hard, smooth mattress, at first lying on his back, and, after a few days, on his stomach so that he can prop himself on his elbows. To make certain that sinking of the mattress cannot take place, boards are placed between it and the bed springs. As soon as the pain caused by the fracture has ceased, the back muscles are massaged (*the patient lying on his stomach*), *and after seven weeks the patient is permitted to crawl on all fours as a regulated form of exercise.* Having become proficient in this exercise, the patient is next permitted to stand, and lastly, to sit. The object of the treatment is to secure perfect anatomic and functional restoration of the spinal column without injuring the spinal cord.

Mock's Method.—By the methods which I have used in treating these compression fractures, the marked restoration of the deformed vertebral body that has been pictured by other methods has not always

Fig. 8b.—Example of plaster cast applied with back in hyperextension and used for ambulatory treatment of fractured spines.

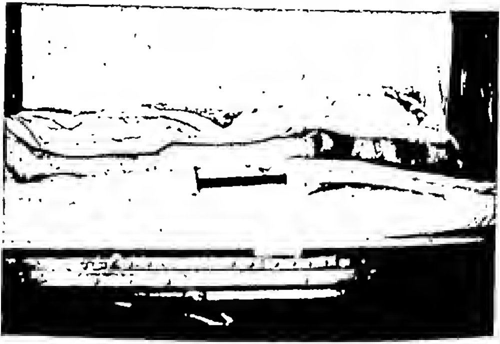

FIG. 9a.—Compression fracture of 1st lumbar vertebra. Patient in hyperextension position on a Bradford frame.

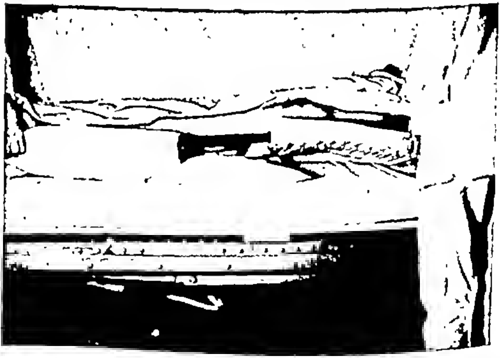

FIG. 9b.—Same case showing method of lifting Bradford frame and slowly turning patient from the frame on to his abdomen on a cart at the side of the bed. This can be done after the third week.

been secured, yet the functional results have, in the majority of cases, been very good. Various methods are used, depending upon the given case, thus:

Rest in bed with traction to head and lower extremities, or traction and countertraction by elevating one end of the bed. A sand bag or firm pillow is placed under the back at the point of fracture to secure hyperextension.

Rest in bed with hyperextension only. In either of these methods, the rest in bed persists for 8 to 12 weeks, depending upon the extent of the injury.

FIG. 9c.—Same patient turned from Bradford frame on to a cart. Note the hyperextension of this spine maintained by pillows placed on the cart and holding chest in raised position. This transfer to the cart is performed daily for the purpose of giving massage to the back muscles.

Usually a Bradford frame is employed. It is bent in the region of the fracture so as to give a marked convexity to the firm canvas bed, thereby providing the desired hyperextension. The frame can be provided with a removable strip of canvas at the buttocks, to facilitate the use of the bed pan. The patient is firmly attached to the Bradford frame by wide flannel binders. Thus, by turning the frame from side to side, the position of the patient can be changed while he maintains his hyperextension, and thus the feared pulmonary complications are prevented. After four weeks, the patient can be turned completely over on the frame, to lie prone upon the mattress. The mattress has sufficient pillows to raise the upper portion of the chest, thereby maintain-

ing the hyperextension. In this position the patient can be taught exercises, such as pushing his chest backward by supporting himself upon his arms, the amount of hyperextension being thereby increased. If the bed has been sufficiently padded and adjusted with pillows, the Bradford frame can be removed and massage can be given to the back muscles. This procedure can be repeated daily after four weeks, and the amount of hyperextension exercise and the strength of the massage can be increased daily. The frame is then reapplied and the patient is turned back into a recumbent position.

Almost from the beginning of this treatment, massage of the extremities, abdomen and chest, and supervised exercises of the upper and lower extremities can be instituted. The technician can even massage a considerable portion of the back without unduly disturbing the hyperextension position of the patient by sliding her hands, one on either side, between the patient's back and the canvas bed of the frame. After four weeks, the amount of massage and exercise can be increased, as described above. After six to eight weeks, the patient can usually be lifted from the frame on to a properly padded mattress. It is well to prevent this mattress from sagging in the middle by placing boards across the bed under the springs. At this stage the patient should be taught to turn over in the prone position and, with pillows under his upper chest, to exercise by raising himself on his elbows or arms, and again, by hyperextending his thighs. These exercises will maintain and increase the amount of hyperextension of the spine. After eight to ten weeks, the patient can be allowed to sit up in bed for short periods and to exercise by bending forward, gradually instituting the flexion exercises. These should be carefully supervised at first, and should follow the massage treatment (Figs. 9a, 9b, 9c).

In from 10 to 12 weeks the patient can usually be around in a wheel chair with weight-bearing starting at the end of 12 weeks, provided symptoms of pain and signs of muscle spasm and sensitive nodes have disappeared. Seldom, and now practically never, is a belt or back brace applied to these patients. For another four to eight weeks these patients are carefully supervised, massage and exercise are persisted in, and home work is started. By the end of six months, the majority of these cases can be back at their employment, even at heavy work.

This treatment is based upon maintaining as large an amount of function in the joints and musculature of the back as possible without further compression of the fractured vertebra, with as great a restoration as possible of the form of the vertebra, and with firm union of the fracture before weight-bearing is allowed. The prevention of thickening and foreshortening of the ligaments, contraction of the aponeurosis, and adhesions and fibrotic changes in the muscles due to atrophy from disuse is held of equal importance to preventing further compression and to securing good healing of the fracture. A certain amount of these changes is bound to occur, therefore the persistence in the massage and exercise until all such changes are overcome is

extremely important. It is very easy for such a patient to begin to hold the back muscles more or less rigid, to develop faulty posture, and otherwise to undo the early efforts, if supervision stops too soon. Heat, of course, is an excellent adjunct to the massage and should precede it. Hydrotherapy in the form of hot tub baths is also efficacious before the massage.

All fractured vertebrae do not fall into the class of the cases just described. Some of them seem to recover completely without any treatment, while others continue to have symptoms in spite of the most careful supervision. The surgeon must use his judgment in the handling of each individual and will find that many will respond to the treatment even more rapidly than those just described. Again, consideration must be given to the forms of treatment now being advocated by many, which allow earlier ambulatory care.

Cervical Fractures.—Fractures in the cervical region usually need immobilization for a period of six or eight weeks. This can be accomplished by rest in bed with a jury-mast traction apparatus, by cast or by specially made neck braces with head support. A combination of traction with the neck brace is most often used. Frequently these braces or a cast is worn for six months.

Massage, which is gentle at first, but which is gradually increased in force, should be started within the first week while the patient is still in bed and in traction. The massage should include the neck, shoulder, and arm muscles. I am opposed to a cast because it prevents massage, and later, exercise. A brace can be removed and massage given. The patient should be placed in bed or on a table and immobilization maintained by sand bags placed on either side of the head during the treatment and then the brace should be replaced. This should be done every day or at least every other day. After four weeks very slight active exercise, such as gently turning the head from side to side, and assisted active exercise, such as helping the patient to lift his head slightly from the table, should be instituted. After eight weeks, provided the x-ray shows no contraindication, the brace can be removed for longer periods each day and the amount of exercise and massage increased rapidly. By the end of 10 to 12 weeks most of the average cases of fracture of cervical vertebrae without cord symptoms should be free of all immobilization and all braces and should have full function in the neck.

I have seen patients with cervical fracture still wearing a brace after six months with stiff neck due to ligament and muscle contraction, who have been told that they must wear the brace for at least a year. Unquestionably, more attention paid to maintaining function in the soft tissues of the neck and more faith in the ability of these fractured vertebrae to heal would obviate the necessity, often born of fear of disaster, of wearing these casts or braces for even six months, let alone a year.

DISLOCATIONS AND SUBLUXATIONS

Dislocations or subluxations of vertebrae require careful manipulation to reduce the luxation or subluxation. If it is in the cervical region, the treatment is usually done under anesthesia. The patient's head and neck protrude over the head of the table and rest in the operator's hands. Then by a combination of traction, gentle but gradual flexion of the neck, increased traction and of bringing the head backward with the neck in hyperextension, the dislocation is overcome. Pressure with the fingers just below or above the site of dislocation is firmly made to act as a fulcrum. In addition, lateral movement of the head, bringing marked lateral flexion of the neck first on one side then on the other, is sometimes necessary. Of course, all manipulation in the neck should be entered into with great caution lest the dislocated vertebrae should be forced into greater deformity and cause compression of the cord.

Rest in bed with early massage should start almost at once, and exercise can start after two weeks. A brace may be worn for four weeks if the dislocation has been completely reduced, or possibly for eight weeks if it has been incompletely reduced. Here again the prolonged wearing of a brace or cast is unnecessary.

Some of these cases can be reduced by applying heavy traction to the head. However, if this fails by the end of the first week, manipulation is indicated.

Luxations and subluxations in the dorsal and lumbar region are extremely difficult to reduce by manipulation. Usually, hyperextension of the back combined with traction will result in sufficiently good reduction to obtain a good functional result. However, it is in this type of case that the patient often complains of pain and weakness in the back for months and years. These results occur too often and the symptoms in the different cases are too similar for them to be classed as neuroses. This is the type of case in which ankylosing operations will often give the best results.

FRACTURE-DISLOCATIONS

Fracture-dislocations are more frequent than pure dislocations. They must be handled as described for pure fractures. In selected cases, especially in the cervical vertebrae, manipulation may be resorted to in order to overcome the dislocation. In other cases operation seems advisable. If the attempt to reduce the dislocation fails, a bone graft operation should be performed to prevent further dislocation and damage to the cord. I have seen only one case where this procedure seemed advisable and necessary.

In these cases the same effort should be put forth as early as possible to give heat, massage, and exercise in order to maintain function and to prevent the dire results of prolonged immobilization of joints.

FRACTURES OF TRANSVERSE PROCESSES

Fractures of the transverse processes are peculiar in their behavior. As a rule they result in immediate disability, with pain, muscle spasm, and tenderness even more marked than in many of the cases of compression fracture, and these symptoms and signs will continue unduly long in spite of treatment. Again, the signs and symptoms will disappear after a week in bed with heat applied to the back, and the patient will begin to insist upon getting up. The physician will catch him sitting up in bed in spite of his warnings and advice. I have seen

FIG. 10—Comminuted fracture of left transverse process of 4th lumbar vertebra.

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prevent thickening and contraction of the aponeurosis. Daily exercises of the legs and arms, active in character, are supervised by the technician. By the end of the sixth week assisted active exercises of the back are started, such as hyperflexing the spine by the patient's lying prone and raising himself on his elbows or hands; later, by his lying on his back and lifting his buttocks from the bed; and finally, by his sitting up in bed, first assisted and later unassisted. By the end of eight weeks, unless the x-ray shows definite contraindications, the average case will have recovered and will need no further physical therapy.

FRACTURES OF SPINOUS PROCESSES

Fractures of the spinous processes are treated approximately in the same manner as fractures of the transverse processes.

FRACTURES OF LAMINAE AND ARCHES

Fractures of the laminae are treated when diagnosed as described for compression fractures. Chandler, of Chicago, has described obscure, often undiagnosed fractures of the lumbar laminae which cause prolonged symptoms and which require bone transplants and fixation. He has done exhaustive work on the subject. Following the operation, of course, there is rest in bed. I would add to this treatment measures of heat, massage, and graduated exercises (Fig. 11).

Sprains of Back

Etiology.—Sprains of the back follow many accidents which are sufficiently serious to give a fracture, but following which x-ray evidence of fracture is lacking. Sudden twists or falls when in a strained position, for example, slipping while straining to lift a heavy object or having a sudden weight thrown upon the straining body, will also often result in sprains of the back. As in any other part of the body, a sprain will cause a certain amount of tearing of the ligaments and attachments about the part, ecchymosis or minute hemorrhages, exudation, and swelling.

Symptoms.—The pain is usually immediate, causing the patient to stop work and rest, but after a few hours it may subside and he may return to work. The next morning or a day or two later he is so sore and the pain is so marked that he cannot get out of bed or he cannot straighten up. The continued use of the back has aggravated the condition.

Diagnosis.—It is extremely important to diagnose a sprain early and to put such a patient to bed at absolute rest. Heat, moist or dry, should be applied at once. If available, diathermy is a valuable means

such patients up and around and apparently well at the end of six weeks even when the x-ray has shown three transverse processes, fractured, displaced slightly, and still ununited (Fig. 10).

Other cases which seem to be making satisfactory progress begin to grow worse and develop into the typical chronic back cases. Too often this change dates from the time the patient is told by another doctor, the interne, the nurse, a fellow patient, or some lawyer or member of the family seeking to magnify the importance of the case, that he has a "broken back."

The term "broken back" is a potential trouble maker. It brings fear and apprehension to the patient. It recalls cases heard of in the past in which the individuals never walked again. It carries ideas of grandeur due to the old days of frequent lawsuits when a "broken back" was usually good for a $10,000 or $25,000 damage.

I am not in favor of withholding from any patient the diagnosis of fracture, but if it was ever justified, it would be in these back fractures, especially of a transverse process. To prevent the above dangers of apprehension from being born in these cases, I usually take time to draw a picture of a segment of the spinal column, show this to the patient, and explain to him how this little transverse process is broken, but that it has no connection with the so-called broken back, that it cannot possibly affect the cord, and that there are so many other transverse processes to take up its function that no great damage can come from it. I then explain that he must keep quiet for six to eight weeks in order to allow the fracture to unite, pointing out that often the union is only fibrous but that fibrous union will be sufficient to give him full and good function of his back once more. In spite of all these precautions, cases of fracture of the transverse process can become exceedingly difficult to treat.

Treatment.—Personally, I prefer to treat these cases by rest in bed for six to eight weeks. The mattress is prevented from sagging by placing boards across the bed underneath the springs. A soft pillow in the small of the back will help maintain the normal lordosis.

Heat should be applied at once in the form of large, moist hot fomentations with large folds of flannel as the agent, the flannel being held in place by a covering of rubber sheeting. A binder is then applied. The applications should be frequently changed and kept very warm. Hot-water bottles, an electric pad, or an ordinary electric light bulb and reflector may furnish the source of heat. As soon as the patient can be turned over on his stomach (he should lie relaxed and let the nurse and technician turn him over), gentle stroking massage is started. At first this is a sedative massage which tends to relax the spasm in the muscles and to relieve the pain. Later, the massage is increased and becomes both stroking and, by the fourth week, kneading or rotary in character. Its purpose now is to increase circulation to these parts, to overcome any muscular atrophy, and to

prolong the condition. Allowing them to remain recumbent for three or four weeks without massage or exercise is only to foster adhesions, painful joints, and a string of indefinite sequelae that usually eventually lead to an erroneous diagnosis of neurosis. Strapping the back with firm adhesive plaster and allowing the patient to go about is better than the last-mentioned procedure provided that the strapping is not too prolonged and that the patient does not develop faulty posture habits. Rest, heat, and massage for the first week, with strapping for the second week, followed by systematic efforts to develop exercise and function, will relieve the majority of these cases within three to four weeks. However, the strapping usually causes pimples and irritation and prevents proper massage. If possible, it should be avoided. Certainly tight strapping or the early and prolonged use of a brace is often another means of causing muscle atrophy, contraction of ligaments, and adhesions.

The commonest location for these sprains is in the low back, usually a lumbosacral or a sacro-iliac condition. The sprain in these regions is too often not sufficiently serious to cause the physician great concern or to justify the patient's going to bed and being fussed with. As a result, inadequate early treatment prolongs the condition, allows it to become aggravated, or results in sequelae which are far more difficult to relieve. The latter will be considered under post-traumatic conditions.

Rest, heat, massage, and graduated exercise are indicated and should start early whenever the history and findings suggest the possibility of a lumbosacral or sacro-iliac sprain. As a rule I never strap these patients, except possibly for two days to a week when they first get out of bed. In a limited number of cases a sacro-iliac belt may be indicated, but placing a sacro-iliac belt on a patient and telling him to wear it indefinitely without daily removal for massage tends only to doom him to invalidism. Four to six weeks should be the limit for the wearing of such a belt. The belt soothes both the patient and the physician, often preventing the early discovery of sequelae that must be treated and removed if full recovery is to follow. A good plan to follow when these patients first get out of bed is firmly to belt the sacro-iliac region by applying an ordinary strap belt just outside the underclothes and passing it around the body just below the antero-superior spines of the ilium. The patient is instructed to remove this for rest periods and for certain exercises. He seldom becomes wedded to such a belt as he does to the more elaborate sacro-iliac braces. Again let me repeat that the latter have their place, but only in a limited number of cases and for a limited length of time.

Some patients will not respond to the above treatment nor to any other form of treatment. Certain of these either are operated on for a fixation of the sacro-iliac joint or become permanent wearers of the sacro-iliac or other form of brace. When I am forced to yield to one

of applying heat and gives the quickest relief from pain. Early massage, rhythmic and applied gently at first but gradually increased in force and carried always in the same direction, i.e., upward and outward, will soon reduce the exudation and swelling. As soon as the pain is relieved or after one week, active assisted and active exercises should start to prevent contraction of the ligaments, thickening of the aponeurosis, and adhesions about the joints.

Treatment.—Allowing these patients to be up and around and to assume faulty postures in order to relieve their discomfort is only to

Fig. 11.—Example of fracture of the lamina of the 5th lumbar vertebra. There is also a slight spondylolisthesis.

prolong the condition. Allowing them to remain recumbent for three or four weeks without massage or exercise is only to foster adhesions, painful joints, and a string of indefinite sequelae that usually eventually lead to an erroneous diagnosis of neurosis. Strapping the back with firm adhesive plaster and allowing the patient to go about is better than the last-mentioned procedure provided that the strapping is not too prolonged and that the patient does not develop faulty posture habits. Rest, heat, and massage for the first week, with strapping for the second week, followed by systematic efforts to develop exercise and function, will relieve the majority of these cases within three to four weeks. However, the strapping usually causes pimples and irritation and prevents proper massage. If possible, it should be avoided. Certainly tight strapping or the early and prolonged use of a brace is often another means of causing muscle atrophy, contraction of ligaments, and adhesions.

The commonest location for these sprains is in the low back, usually a lumbosacral or a sacro-iliac condition. The sprain in these regions is too often not sufficiently serious to cause the physician great concern or to justify the patient's going to bed and being fussed with. As a result, inadequate early treatment prolongs the condition, allows it to become aggravated, or results in sequelae which are far more difficult to relieve. The latter will be considered under post-traumatic conditions.

Rest, heat, massage, and graduated exercise are indicated and should start early whenever the history and findings suggest the possibility of a lumbosacral or sacro-iliac sprain. As a rule I never strap these patients, except possibly for two days to a week when they first get out of bed. In a limited number of cases a sacro-iliac belt may be indicated, but placing a sacro-iliac belt on a patient and telling him to wear it indefinitely without daily removal for massage tends only to doom him to invalidism. Four to six weeks should be the limit for the wearing of such a belt. The belt soothes both the patient and the physician, often preventing the early discovery of sequelae that must be treated and removed if full recovery is to follow. A good plan to follow when these patients first get out of bed is firmly to belt the sacro-iliac region by applying an ordinary strap belt just outside the underclothes and passing it around the body just below the antero-superior spines of the ilium. The patient is instructed to remove this for rest periods and for certain exercises. He seldom becomes wedded to such a belt as he does to the more elaborate sacro-iliac braces. Again let me repeat that the latter have their place, but only in a limited number of cases and for a limited length of time.

Some patients will not respond to the above treatment nor to any other form of treatment. Certain of these either are operated on for a fixation of the sacro-iliac joint or become permanent wearers of the sacro-iliac or other form of brace. When I am forced to yield to one

or the other of these plans, I feel that in some way my ideals of treatment have miscarried or have been cheated.

Strains of Back

Strains of back usually occur from less severe injuries than those which result in sprains. In strains the signs and symptoms are not as severe as they are in sprains. Failure, however, on the part of the physician or patient to recognize these strains and to treat them as potential trouble makers often results in prolonged disability.

They can usually be treated as ambulatory cases, but if the signs and symptoms begin to grow worse or are prolonged for more than a week, I favor putting the patient at absolute rest and treating him as described for sprains. The ambulatory treatment consists of applying a firm binder and having the patient report daily for heat, massage, and graduated active exercises. The patient is instructed to take one or two hot baths a day at home, in between treatments. I have seen a patient with simple strain who reported to the physical therapy laboratory for treatment grow markedly worse after the treatment. This usually occurs in the winter. He is baked and massaged in the warm office, goes out into the cold, rides home on a cold street car, and that night develops a severe attack of lumbago or myositis. Physicians should recognize this danger, and if the patient complains of "catching cold" after office treatment, some form of home treatment should be substituted. A baker to use in the home can be made or bought very reasonably, or the physician can rent or lend one to the patient. The technician can report to the home daily to give the heat and massage. Unquestionably more attention must be paid to the effect upon the patient of ambulatory physical therapy than has been done in the past.

Lumbago, Myositis, Myofascitis

Lumbago, myositis, and myofascitis are all terms used to denote an acute painful back. The attack usually comes on suddenly and often after some minor injury or, more often, after some unusual strain, such as overlifting, or after a change from a rather sedentary occupation to very active or heavy work.

This Thanksgiving at a family reunion I played a strenuous game of old-fashioned shinny with a number of my male relatives. Several of our sons were college boys, and while the old guard won the game, yet we were hard-pressed. It was a moderately cold day. We became very warm and then cooled off rapidly. Within two hours I had a severe lumbago. It persisted untreated for two days and then disappeared. Was this due to strain, to the rapid heating and cooling of my body, or to a focal infection? I have no other evidence of a focal infection.

We undoubtedly have traumatic lumbago and lumbago due to infec-

tion. Search should be made for the infection in all cases of persistent or recurring back pain. The rapidity with which a lumbago will disappear after an abscessed tooth has been pulled has been noted many times. However, all painful backs have not yielded to the loss of a tooth or even of all the teeth. Other causes must be searched for before too many teeth, tonsils, gallbladders, etc., are sacrificed.

The treatment of these strain-lumbagos when they persist is rest, heat, massage, and graduated exercises. Often they will yield best to infra-red baking. The ordinary electric glow for heating a bathroom is one of the best infra-red bakers that can be secured.

Locking of Vertebral Joints

Acute locking of some of the vertebral joints, possibly a ligamentous dysfunction rather than a slipping or slight dislocation, occurs. The condition is most common in the cervical region and in the neighborhood of the twelfth dorsal and first lumbar vertebrae. It is a peculiar phenomenon and often manifests itself in the cervical region by a sense of sudden pain, followed at once by a burning sensation in the neck, and later, by a momentary or temporary stiffness; then it subsides. Occasionally it will be more severe, will persist, and will require treatment. In a recent newspaper the case of a woman who dislocated her neck by suddenly turning her head was described. From the description of the case I believe it was one of acute locking. A year ago my son grabbed his sister playfully about the neck and bent her backward. She cried out, held her hand to the back of her neck, and could not move her head, which was held in a fixed, slightly turned position. I was home at the time and immediately went to her assistance. The head was fixed, evidently by some locking, in the region of the second to the fourth cervical vertebrae. I had her sit on the floor, placed a hand on either side of her head, and lifted her upward, allowing her body weight to be the force of traction. At the same time I gently manipulated her head from side to side. There was a sensation of a sudden slip or give in her neck and she immediately exclaimed that now it was all right. Only a slight temporary soreness followed.

Similar examples of locking have occurred following the hitting of a bump and then being thrown upward and backward when riding on the back seat of an automobile. In one such case examined two days after the accident the patient had a painful stiff neck with very little head movement. The x-ray was negative. This case yielded to manipulation followed by heat and massage for three days. A farmer boy was seen by me at his home in the country. He had terrific pain in his back located in the region of the twelfth dorsal vertebra. His physician had given him hypodermics of morphine without any relief of the pain. The condition had followed the lifting of a heavy grain sack. The tenderness was marked over the twelfth dorsal vertebra and the first lumbar joint. He could not stand examination, let alone manipulation.

We were not prepared to give him an anesthetic and the family refused to allow removal to the local hospital. Traction was applied to his legs, the foot of the bed was elevated, and a pillow was placed under his back. He continued to suffer for almost a week, when the pain suddenly disappeared. Mennell[7] describes acute locking of the costal vertebral joints and gives very well-defined methods of manipulation to overcome these. Although physical therapy is seldom needed in these cases, yet physical therapy and manipulative surgery are so closely related that it seems proper to mention them here.

Similar lockings may occur between two adjacent transverse processes or between an elongated spinous process and its fellow. Manipulation is necessary for relief. Prolonged pain following some of these cases of locking between vertebrae are undoubtedly due to a persistent synovitis. Heat, massage, and gradually increasing exercises are likewise indicated in these cases.

Wryneck

Wryneck or stiff-neck is almost as common as lumbago. The ordinary case will usually disappear without treatment or with heat and massage. Wryneck following injury to the cervical vertebrae or to sprains in this region often requires prolonged treatment by heat, massage, and graduated exercises.

Posttraumatic Sequelae

Any surgeon doing a considerable amount of reconstructive surgery will see a great number of traumatic cases weeks and months after the acute injury. They are referred for treatment to overcome certain sequelae which are the result either of the injury or of the treatment given. A high percentage of these cases are back injuries.

Old Fractured Vertebrae without Cord Injury

Etiology.—The persistence of symptoms in cases of compression fracture of one or more vertebrae or of fractures of the transverse or spinous processes beyond a period of three months usually indicates that certain sequelae have developed which must be discovered and treated if the given part is to secure complete functional recovery. The usual causes for these persistent symptoms are:

A. Failure to diagnose the fracture and to institute proper treatment early. Negligence in taking a lateral x-ray picture is the commonest cause of diagnostic failure.
B. Too short a period of active treatment of the fracture.
C. Too prolonged a period of active treatment by a cast or other forms of immobilization.
D. Too much dependence upon a back brace.

E. The surgeon's waning interest in the case after two or three months.

F. The development of functional neuroses.

The following short résumés of cases illustrate these conditions:

CASE 7.—Mr. C. S., 35 years old, was treated five months for a sacro-iliac condition. He had been kept in bed for a month, was fitted with a sacro-iliac belt, was given light treatments, and was finally told to go to work. He attempted light work, but the next morning he could not stoop over to pull on his shoes. He was seen several times by his doctor, but the latter had "seemed to lose interest in my case," according to the patient. He was finally referred to St. Luke's hospital where he came under my care.

Examination showed a definite point of tenderness which was constantly located, at each examination, directly over the fourth lumbar vertebra. Movements of the back, especially when he attempted to straighten up from a stooping position, caused definite rigidity or muscle spasm in the erector spinae muscles of this region. From the history of the case and from these findings a diagnosis of probable fracture of the fourth lumbar vertebra was made and the x-ray was then ordered. The lateral view showed that a small wedge of the body of the fourth lumbar vertebra was broken off and displaced anteriorly. There was a slight depression of the anterosuperior border of the body of the fourth lumbar vertebra. The anteroposterior view failed to show any evidence of this injury.

The case was reported as one of fracture. The original doctor was asked to mail in his x-rays so that we could see if this was present at the time of the original injury. His x-rays had been made only in the anteroposterior view. My x-rays and the original x-rays were then submitted to another roentgenologist, who called the condition an osteo-arthritis. They were then submitted to Dr. Hollis Potter, who said that the condition was a fracture and pointed out that osteo-arthritis must always involve the articular surface which was not affected in this case (Figs. 12a, 12b).

The patient's pain and muscle spasm were due to the prolonged immobilization of the back muscles and joints by the sacro-iliac brace, to holding them stiff because movement caused pain, and to periods of attempting active exercise and work before he was ready for them. Certainly there was no surgical treatment indicated to remove or replace this wedge. Further immobilization offered neither temporary nor ultimate relief of the situation.

The treatment instituted was first to explain the condition to the patient in common sense terms and to secure his coöperation. Then he was put to bed, and the back baked and hot fomentations applied alternately every two hours. Massage once a day was started immediately. Simple, very graduated exercises were given at each period of massage. Whenever pain or muscle spasm appeared, the exercises were stopped and were not carried to that point again for three days. After two weeks he was allowed to go to the physical therapy department in a wheel chair for the same treatment. After another week he was allowed to walk about and to go to the occupational therapy department for light work. He was discharged at the end of eight weeks, cured, not of a broken back (for this fracture had healed, albeit with slight deformity, long before I saw the case), but of the soft-tissue ankylosis which had developed from prolonged immobilization and disuse and which caused

muscle spasm and pain whenever undue stress was applied to these back joints.

CASE 8.—Mr. O. S., aged 57, a railroad engineer, suffered a compression fracture of the third and fourth lumbar vertebrae. He weighed 200 lb. He was kept at rest in bed for six months and was then fitted with a back brace. *He had not been able to return to work. He was referred* to me to ascertain if anything further could be done or if this man should be pensioned.

Examination revealed a very heavy, short man who weighed 240 lb., having gained 40 lb. during course of rest and treatment. His back was held rigid in a leather and steel back brace. The muscles were slightly rigid on

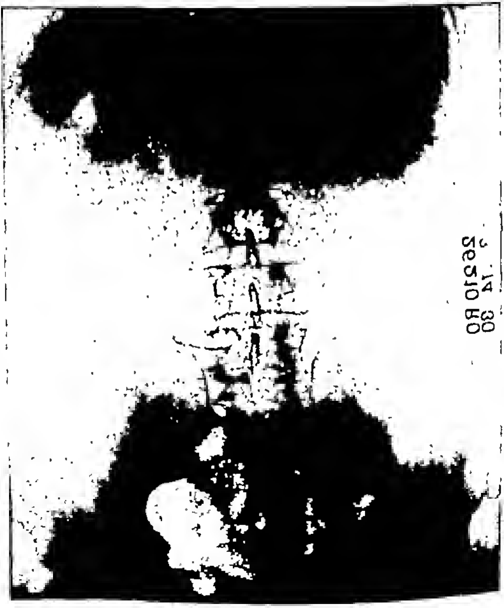

FIG. 12a.—Anteroposterior view of Case 7 failed to show any evidence of fracture.

motion, but there was no muscle spasm. The patient's chief complaint was pain and weakness in his back when he attempted to go without his brace. In addition, he had swelling of the ankles which had developed since he was allowed out of bed, and he had flatfeet. His basal metabolism was normal.

FIG. 12b.—Lateral view of Case 7 showing a definite compression fracture with displacement of the fragment in the 4th lumbar vertebra.

Physical therapy, a reducing diet, foot exercises, and gradually giving up his back brace resulted in improvement in the back muscles, the disappearance of the swelling in the lower legs, and the loss of 20 lb. in weight. At the end of six weeks he was going about constantly without his brace and without complaints. He was allowed to go to his home in Ohio. In four weeks he returned to us with the ankles again swollen and wearing the brace. He refused to stay for further treatment and has since been retired on a pension.

The broken back, of course, was the exciting cause, but his great gain in weight, his becoming wedded to a back brace with its accompanying weakening of the back muscles and stiffening of the back joints, combined with a spirit of giving up and accepting a pension, were the real causes of this man's disability. All these could have been prevented and overcome if he had been willing to put up a fight.

Case 9.—A. R., who was injured in an automobile accident in Michigan, was taken to a hospital and an x-ray (anteroposterior view only) was made of his back. No fracture was found. He was kept in bed for two weeks with a diagnosis of a contused back and was then discharged. He returned to his home in Chicago and was under the care of an osteopath for two weeks. Then he consulted a lawyer and started suit against the owner of the automobile. His lawyer referred him to a doctor who x-rayed his back and in the lateral view discovered a compression fracture of the first lumbar vertebra. (See Figs. 4a, 4b.) He reported to this doctor daily for light treatments. No massage was given. At the end of 10 weeks the insurance company involved referred the patient to me, with the consent of his lawyer, for examination. I found the evidence of the 10-weeks' old compression fracture which had practically gone untreated. The patient had muscle spasm and pain on attempting any undue flexion movements of his back. The pain and muscle spasm, however, caused the patient to hold his back quite rigid. As has been frequently noted, this protective immobilization of the spine can cause partial ankylosis by contraction changes in the soft tissues about the spinal joints.

The patient was more anxious to secure a good recovery from his fractured back than to secure a large settlement. He agreed to take treatment and was very coöperative. He was referred to our physical therapy department for daily treatment consisting of baking the back (heat), massage, and graduated exercises. I could see no reason to treat the fractured vertebra after 10 weeks by putting the patient to bed or by applying a back brace. These would only have added to the stiffening process which had already begun in his back. At the end of a month his case was settled for a small amount and he returned to his regular employment of traveling salesman.

The above cases illustrate that it is not the fractured vertebra *per se* that gives the prolonged disability in back fractures, but the often obvious, at other times obscure, sequelae that follow in the wake of such fractures.

Treatment.—All during the active treatment every effort should be made to keep up muscle tone, normal body functions, and a good mental attitude. As soon as such treatment is safe, exercises should be added to prevent loss of joint function. Then, as the case becomes

ambulatory, belts or braces that may undo all these efforts should be avoided as far as possible; if they are applied, the period of wearing them should be limited to only a few weeks. Start more active heat, massage, exercise, and occupational therapy as soon as the case is ambulatory, and persist in these until full function and working ability are regained. Do not allow your interest in the case to wane until the patient has recovered. There will really be no need of a convalescent period after treatment has stopped if this program is carried out.

Recently I examined a girl with a compression fracture of the second lumbar vertebra. She was being treated admirably. Her doctor remarked that one of the nurses in this hospital had suffered a fracture of her first lumbar vertebra six months ago and that now she was doing full duty. A little later he sent for this nurse. She was a healthy, very cheerful girl, standing very erect and in response to the doctor's question, "Are you wearing your back brace?" she replied, "Oh, yes, I couldn't do without it."

On further questioning, the nurse gave the following information:

"I was in bed seven weeks and then they put on this brace and I was able to be up and around and went back to duty at the end of three months. Yes, I leave the brace off at night and try for a few hours once a week to get along without it, but I soon get so tired and my back is so weak and sore that I am glad to put it back on.

"Oh, I feel so good and am held up so straight by this brace that I don't mind wearing it at all."

This nurse was becoming wedded to her back brace. Her doctor agreed with this and was deeply interested in my suggestions. This hospital has an excellent physical therapy department, and yet this nurse had never been given massage and back exercises. I suggested that these should be started and that each day she should go an hour longer without her brace. As the strength and function of the erector spinae muscles returned, she should be able to leave off the brace altogether, probably at the end of three weeks. She had been told to wear the brace for a year. At the end of that time some such a program would be necessary anyway. Her fracture was long since healed. Why continue to wear the brace for a year and make it even harder to go without it at the end of that time? Ask any lady who used to wear a corset constantly how it made her feel at first to do without it.

Old Sprains of the Back

The majority of these sprains, which have symptoms persisting far beyond the period when recovery should have occurred, are located in the lumbar region of the back—usually in the lower lumbar and in the vicinity of the sacro-iliac joints.

Symptoms.—Sprains in the cervical region usually manifest themselves by varying degrees of wryneck and yield more readily to heat

and massage, even the massage the patient gives his own neck muscles. Occasionally one will see persistent symptoms from such sprains where some form of neck brace or collar has been used for immobilization for any considerable period. Such conditions will yield to heat, massage, and graduated exercises. Sprains in the dorsal region are uncommon. Here, again, persistence of symptoms too often is the result of prolonged immobilization. Therefore attention must be directed chiefly to these old persistent sprains in the lower lumbar region.

Etiology.—They are usually due to inadequate treatment during the acute condition wherein the patient is allowed to remain ambulatory, but, because of the pain on movement, he holds his back quite rigid—a condition of self-protecting immobilization. One sees a similar condition in bursitis or other acute affections about the shoulder joint when the patient, for the purpose of relief or protection from pain, carries the arm adducted to the side of his body. After a few weeks it becomes more or less fixed in this position.

Another cause for these old sprain cases in the back is too prolonged an immobilization by treatment. The patient is kept in bed, without any effort at physical therapy, for three or four weeks; then, because he still has pain, a brace or a wide belt is applied which continues the immobilization. Effort to use these back joints causes the same pain and discomfort that occur in any other part which is unduly immobilized.

Pathology.—There are signs and symptoms described to differentiate between a sacro-iliac and a lumbosacral sprain, but these are not always conclusive. The pathology in either case is the same, viz., contraction and thickening of the joint capsule, thickening of the aponeurosis, foreshortening and contracture of muscles due to their being held in the position of greatest comfort; and adhesions which have formed at the site of the exudate and the slight hemorrhage which accompanied the original sprain. When one visualizes the sprains in back joints just as he does the common ankle sprain, he then better understands the possibilities.

Diagnosis.—These cases are often extremely difficult to diagnose. Many of them have developed neuroses—"misunderstood neuroses," I call them. The patient's suffering is misunderstood by the doctor and the family who often make the patient feel that there is not much wrong with him. The patient soon develops an attitude of being misunderstood. He will not talk of his condition except with sympathetic friends, and he soon begins to search for sympathetic listeners until he gets the habit of talking about his ailment. The patient cannot explain the peculiar spasm in his back on certain movements, his doctor cannot find a cause for it, he develops secret fears and worries, and he unconsciously begins to exaggerate his complaints and to magnify

certain signs when being examined. He cannot understand why his trouble persists, why he cannot be relieved, why his doctor cannot find a cause. In short, a chain of misunderstanding develops which leads to this rather frequent development of neurosis in back cases.

A pure back neurosis is not common. Underneath the nervous phenomena are usually one or more organic conditions in the back which, when discovered and relieved, cause the neurosis to fade away.

The x-ray is usually of no avail in the diagnosis of these old sprains.

The ordinary physical findings may be of little help. Usually, however, a systematic, careful, routine examination of all the back, hip, and leg movements will show that certain ones of these are restricted or are causing more pain than other movements. Occasionally there are symptoms of a sciatica.

Sciatica

Sciatica, if of several weeks' standing, will show the distribution of pain somewhere along its course, tenderness on palpation over the course of the nerve, atrophy most often in the thigh, and a weakened or absent Achilles reflex. Such findings are always suggestive of definite organic changes in the lumbar region.

Finally, I often resort to examination of these patients under anesthesia in order to prove positively where and to what extent motion is restricted.

Case 10.—Mr. W. came to me with a history of back disability of five months' standing. He was leaning over to his right lifting a 25-lb. battery with his left hand when his left foot slipped from under him, throwing him in a side-twisting movement to the left. He was in severe pain for a time, then it eased and he continued to work for the next four days. Each day his back pained him a little more and he was a little stiffer on arising each morning. On the fifth morning he tried to arise and could not move, unassisted. His wife helped him from bed and he managed to dress. When he leaned over to pull on his shoe, a spasm of pain attacked his back and he could not straighten up. He was finally helped back to bed and the doctor was called, who had him taken to a hospital. An x-ray examination was made, but it showed no fracture. He remained in bed for four weeks and then was allowed to go home. Pain was still present and therefore a wide canvas back brace with steel supports was made and he wore this constantly until he reported to me four months later. For weeks this patient reported to his doctor's office where light treatments were given to the back. He was thoroughly tanned over the back and left thigh. At the end of two months he had developed pain down the left thigh and leg. This became so bad that he could not walk. Neither could he sit on a chair for more than 10 min. without shifting all his weight to his right buttock. He was miserable and yet he felt that "folks thought he was putting a lot of it on." He said, "I would much rather work and make my $35.00 per week than to loaf and draw $16.00 a week—what do they think I am?" He had certain neurotic signs and symptoms—a "misunderstood neurosis"—and my interne, after examining this patient, told me that he was a "neuro."

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The examination when he entered my service at St. Luke's Hospital was negative except for slight restriction of motion on flexing the left thigh on the abdomen, pain on forcing further flexion, and tenderness over the left sciatic nerve with definite muscle atrophy in both the left thigh and calf and absence of the Achilles tendon reflex. The patient localized the pain each time in the neighborhood of the left articulation of the fourth and fifth lumbar vertebrae and from there down to the ilium near the posterosuperior spine.

This patient was given an anesthetic and examined. When both thighs were flexed upon the abdomen as far as possible, it was quite noticeable that the right thigh would flex from three to four inches nearer the abdominal wall than would the left. This was the only motion that seemed limited.

Treatment of this case consisted of the following:

Manipulation.—With the patient anesthetized, my assistant flexed the right thigh while I flexed the left thigh as far as was possible without undue pressure. The thighs were then alternately extended and flexed, rocking the patient's buttocks off the table and each time bringing both thighs as nearly as possible into contact with the abdominal wall. Soon there was a sensation of soft crepitus or of "giving" in the left side of the back near the fifth lumbar vertebra and ilium. With each rocking the left thigh came more into alignment with the right on complete flexion. The manipulation was continued until both thighs flexed equally.

Those who observed the manipulation and felt the "giving" of the soft tissues in the small of the back agreed that we had broken up some old adhesions or had stretched thickened ligaments and muscles until the restricted flexion of the thigh had been overcome. This procedure was done gently rather than forcibly (Figs. 13a, 13b).

Immediate After-care.—The patient was returned to bed and large hot fomentations were applied to the back and changed every two hours. At each changing the patient turned on his stomach and a large baking light was placed over his back. Thus there was no sudden cooling of the back. He was encouraged to exercise his legs often and to flex them as far as possible. A gentle but stimulating massage was given the same afternoon. This treatment was continued all night with massage the next morning, followed by assisted exercises. The technician was shown the nature of these exercises which consisted of flexing both thighs upon the abdomen as far as possible with mild but steady pressure made upon the left thigh to increase its flexion range. The massage included the left leg from the foot upward.

Continued Treatment.—After the third day this patient was taken to the physical therapy department in a wheel chair and there the larger baker furnished heat to his back and leg for 30 minutes to one hour. This was followed by approximately one hour of steady, ever-increasing-in-force massage. Assisted and active graduated exercises were then given. After a week tub baths of hot water for 20 minutes followed by a brisk rub and the application of heat to the back and leg on returning to bed were added.

This patient was constantly encouraged and every effort was made to overcome the attitude of being misunderstood. Occupational therapy consisting of basketry was started the first week. This had nothing to do with the back muscles but was a great mental diversion and helped materially.

FIG. 13a.—Case of sciatica, left side, developing after lumbosacral sprain. Examination under anesthesia showed limitation of thigh flexion.

FIG. 13b.—Relative position of both thighs after manipulation. The limitation of flexion movement in left thigh has been overcome. (See Case 10.)

After three weeks this patient was able to sit for an hour without pain in the region of his left buttock. The pain and tenderness along his sciatic nerve disappeared, and he could walk about the ward for a short distance without the pain's returning. At this stage he spent an hour in the occupational therapy workshop pedaling the jig saw with his feet and standing at the work bench.

At the end of five weeks the patient felt that he was so much better that he could return home and carry out the treatment there. He left against my better judgment. He returned in three weeks with the condition aggravated but not as bad as at first. He has agreed to remain until cured which will take from 8 to 12 weeks. He is now under his final treatment consisting of heavy exercises, long walks, and rather heavy work in the workshop. Figures 14a and 14b show this patient exercising on a rowing machine.

This rather lengthy résumé serves to illustrate the methods of diagnosis, the manipulative surgery, and the physical and occupational therapy so often necessary to overcome these old persistent back sprains. Each case is a problem unto itself and must often be handled in a different manner, but the physical therapy maneuvers given in this case, if persisted in sufficiently long, will result in a cure in most cases. Occasionally when progress seems to stop, further study is necessary to find the cause. It may be necessary to repeat the manipulation under anesthesia two or more times. Continued interest in the case and persistence in treatment are of paramount importance.

Congenital Conditions

Congenital conditions associated with injury are most frequently found in the lower lumbar and sacral regions.

Spondylolisthesis

Etiology.—Spondylolisthesis, or an anatomic slipping of one vertebra on another, may be congenital or the result of trauma. Great attention has been paid of recent years to the abnormally acute angle formed by the fifth lumbar and the first sacral vertebrae. At times this is so marked that all the weight of the trunk seems to rest upon the vertical sacro-iliac joints and very little support is offered between the fifth lumbar vertebra and the sacrum. Usually in these cases there is a more marked lordosis in the lumbar region. A condition of hyperlordosis may result in a gradual stretching of the ligaments in this region, and when some sudden torsion or rotation strain occurs as the result of a mild or severe trauma, the symptoms of a strain or sprain of the lumbosacral region develop. This abnormality is often associated with faulty posture. The slight lifting or the sudden turning which is blamed for the condition is usually only the "last straw," the real cause being the congenital condition, the faulty position, and the years and years of continued strain exerted upon this joint. There is

FIG. 14a.—Mr. W. (Case 10) exercising on a rowing machine eight weeks after manipulation of the back for lumbosacral sprain and sciatica.

FIG. 14b.—Same case as Fig. 14a exercising on rowing machine.

should then be put at rest on a firm, straight bed with increasing amounts of firm pillows added to the lumbar region to preserve the benefits of the manipulation and gradually to increase the lordosis.

Continuous heat, daily massage, and graduated exercises should be added to the treatment of manipulation. The effort should be made to relieve the pain, cure the sprain, and restore the patient to normal if possible without resorting to immobilization and support.

In older individuals the fixity of the joints and soft tissues may prevent correction, and the only relief may come from back support by a suitable brace.

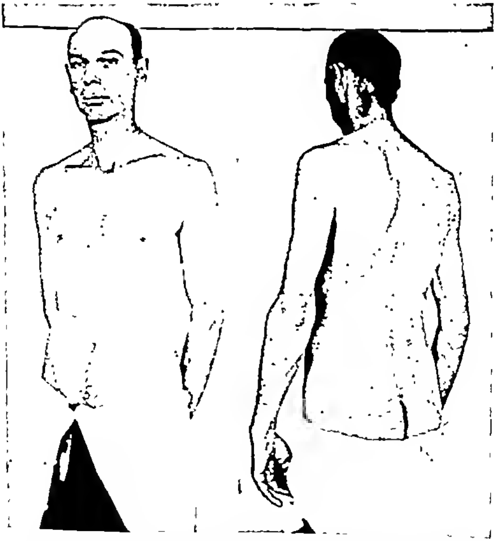

FIG. 15.—Examples of patient with flat back who suffered constant low back pain until he was taught proper posture and exercises to overcome the condition

no wonder that complicated questions arise in these cases, when compensation is involved, considering the insignificance of the alleged accident as a causative factor as compared with these other conditions in no manner related to the accident.

Treatment.—The treatment of such an injury should be upon the same principles as those laid down for lumbosacral sprains—rest, heat, massage, and very carefully guarded and graduated exercises. Great attention should be given to the exercises aimed at correcting faulty posture. Many of these cases are far advanced in years before the joint finally weakens and the "last straw" force lays them low. Often the back pain will persist in spite of all that can be done, and relief is secured only by wearing of a suitable support. Such a support should aim at the correction or the support of the "pot belly" as well as the immobilization of the lumbosacral region.

Flat Back

Flat back, or a loss of the lumbar lordosis, usually shows an abnormal lessening of the lumbosacral angle. The condition receives very little consideration and yet it may cause even more marked disability than the hyperlordosis. Individuals suffering with it tend to suffer strains or sprains more readily. The mechanism for correction is the same as for the opposite condition (Fig. 15).

Diagnosis.—Patients with a flat back can usually be recognized by inspection which will reveal the characteristic flatness of this area; when they lie upon a flat table, all the lumbar spinous processes rest on the table; the characteristic movements of this region are lost, for example, on flexion and extension, the lumbar spines seem to move as one bone somewhat similar to a poker back, and finally, these patients cannot increase the lordosis by raising their bodies from the table with the weight resting upon the shoulders and feet, with the lower legs flexed.

In the absence of all other physical findings and of negative x-rays, if an individual shows these characteristic signs of flat back, one should suspect a sprain aggravated by this congenital condition.

Treatment.—In younger individuals manipulations, usually repeated at intervals and, if necessary, given under an anesthetic, may be employed. The purpose is gradually to lift upward on the lumbar vertebrae and endeavor to increase the lordosis. With each manipulation the same flexion of the thighs upon the abdomen and the stretching of the back muscles, ligaments, and adhesions should be employed as described for manipulations in sprains of this region. The patient

should then be put at rest on a firm, straight bed with increasing amounts of firm pillows added to the lumbar region to preserve the benefits of the manipulation and gradually to increase the lordosis.

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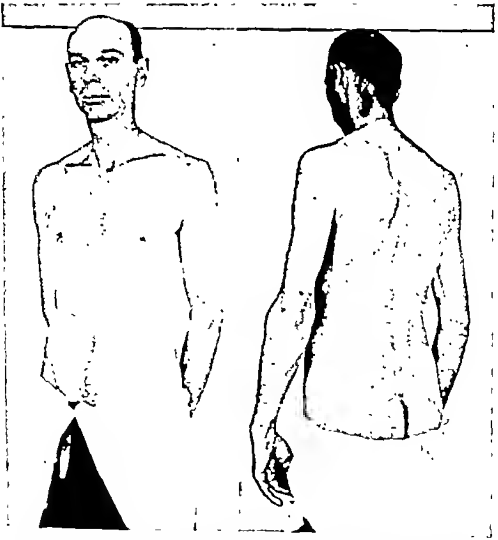

FIG. 15—Examples of patient with flat back who suffered constant low back pain until he was taught proper posture and exercises to overcome the condition

Sacralized Fifth Lumbar Vertebra

This is not an uncommon anomaly. It is seen in a great number of cases x-rayed for other conditions, and in the vast majority of these absolutely no symptoms of discomfort or disability can be elicited. In other cases, however, in which there is backache, and in which the x-ray picture shows this defect, we are probably too prone to attribute the trouble to an impinging fifth transverse process. Unquestionably there are injuries to the back in which these do play a part. There are probably other cases of low back pain not related to injury that cannot be explained upon any other basis.

Pathology.—This congenital condition generally shows a sacrum set low between the ilia with one or both fifth transverse processes impinging upon the sacrum. Usually one of the fifth transverse processes is widened and sometimes irregular in form and lies in close apposition to the sacrum on that side. At times a definite articulation may be seen between the two.

Etiology.—Injuries to this region may occur in many ways. A restriction of motion due to the enlarged process must exist with an imbalance between the two sides which conceivably could make the opposite side more prone to strain. A sudden torsion or lateral flexion of the body toward the side of the anomaly could cause a bruising of the process or the sacrum; a pinching or contusion of the soft tissues lying between; a traumatic arthritis if an articulation had developed between the two. I am convinced that I have seen several cases in which the entire trouble was due to this congenital condition combined with an injury.

Mennell,[7] in a recent book entitled *Backache*, describes a patient who suffered an injury to his back and in whom the x-ray findings suggested the possibility of an impinging fifth transverse process. The patient died of a pulmonary hemorrhage during the course of treatment. He describes his findings at the autopsy and his conclusions as follows:

> Thanks to the courtesy of Dr. Weir, who performed the postmortem examination, I was able to turn my attention to the lumbosacral junction. This we dissected out with care, and found that certain movements of the trunk caused the thin edge of a chisel to be so firmly nipped between the tip of the elongated transverse process and the top of the sacrum that it was impossible to withdraw it without the exercise of extreme force. No false joint could be detected between this transverse process and the top of the sacrum, and it at once became obvious that, when this movement was performed during life, the soft structures between the transverse process and the top of the sacrum must have been pinched very severely. The most prominent point in the examination of this patient during life was that, in the sitting position, rotation of the trunk in one direction was painless, while

rotation in the other direction greatly augmented the symptoms of which he was complaining, particularly when the trunk was inclined backward. Moreover, the fact was quite definitely established that only rotation in the one direction had this effect, and the whole of the rest of the examination, which has been previously explained, was completely negative. So, too, on postmortem examination it was only the one movement which caused the nipping between the transverse process and the sacrum—a nipping which it was quite impossible to secure on the opposite side in any position.

Of course there is always the danger of basing an opinion on the examination of any one case, but when years of experience in dealing with an immense mass of material lead to entire change of opinion, and when the one case in which examination was possible entirely confirms the clinical experience on which this *volte-face* was based, the value of this one case is materially enhanced. It is unlikely that an opportunity of repeating the investigation will occur; and, from a technical point of view, the occurrence of even this one case must be regarded as a piece of extreme good fortune.

The question will, of course, be raised how this particular patient, whose life had been spent in ordinary, laborious work, had been able to carry on, year after year, without symptoms, in spite of the fact that this enlarged transverse process had undoubtedly existed throughout his working years. If we are to attribute the symptoms from which he was suffering to the presence of this transverse process, there can be only one possible explanation, which is as follows:

The ligaments connected with the lumbosacral junction are of a complexity and a strength which can be described only as immense, and it is to be presumed that these ligaments are so arranged that, in ordinary life, movement to an extent which will allow the production of symptoms is prohibited. Thus, as long as these ligaments remain intact, unstretched, and uninjured, an individual can carry on free from symptoms, in spite of structural abnormality. When, however, as the result of accident, undue strain is thrown upon these ligaments, a stretching, which only adds an infinitesimal amount of mobility to the joints, may none the less be sufficient to allow just enough mobility of the tip of the transverse process to cause a nipping of the soft structures, and thus to produce symptoms.

The abnormality may be suspected as the cause when pure rotary movements to one side or the other increase the pain in this locality. When this congenital anomaly is present, in the absence of other findings, it should always be considered in the light of a causative factor. The following case is illustrative:

CASE 11.—C. F., aged 40, was thrown backward by a sudden jerk of a train and struck his back forcibly against a stove. He was twisted sideways and the small of the back was bruised. He was taken to a local hospital where an x-ray picture was made but he was told there were no fractures. His back was strapped, and he was allowed to go home. Symptoms increased and he could not move his back without excruciating pain. He reported to the doctor for "light treatment," and after three weeks a strong back brace was made for him which he wore constantly, sleeping in it for the first

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sage, which was increased gradually in force. After two weeks when pain had been eliminated he went to the physical therapy laboratory for the same treatment plus graduated exercises. Within four weeks he was working in the occupational therapy department—work which necessitated bending to the left to pick up objects (Fig. 16).

He has recovered for the time being, but probably some rather trivial accident will cause another attack. In these cases there are other lines of treatment which are advocated.

Treatment.—Operative treatment is advocated by several good surgeons who advise the removal of the offending transverse process. Some good results have been reported. On the other hand, I have seen two patients who had been operated on, and yet both of them had continued trouble. Personally I believe operative treatment should be limited to only a very few cases, these to be chosen from younger individuals who fail to react to proper physical therapy management. After operation the same physical therapy treatment must be given to insure complete recovery.

Immobilization by a supporting or fixation brace to prevent the movements which cause pain may also be adopted. If the brace is to be eliminated finally, most cases will need careful physical therapy management.

Spina Bifida

Spina bifida is a congenital condition quite frequently seen in x-rays taken because of complaint of back pain following some injury. As a rule the condition is simply noted, but no connection with the injury is considered. Mennell calls attention to the fact that occasionally the upturned incomplete spinous process of a spina bifida may lie close to the adjoining vertebra and that soft tissues may be pinched between these on certain movements.

The frequency with which this condition, as well as other anomalies, is found in the lower back in injury cases compared with the infrequency of their findings in x-rays for other conditions makes one conjecture on the probability of inherent weakness in the spine due to spina bifida as a predisposing cause to trauma.

Spinous Process Anomalies

Bifurcated spinous processes may cause pain by catching a ligament or by locking on certain movements. Occasionally they may be so angulated as to impinge on the adjacent spinous process. Mennell again points out that this latter condition may cause a pinching of soft tissues on certain movements.

The treatment recommended by Mennell for these conditions is the wearing of a belt with a plate fitted to the region of the spine to prevent overextension, the movement which usually causes the pain. One should consider operative removal of the offending spinous process.

month. In spite of this treatment his disability continued. Whenever he left the brace off, the pain and discomfort would grow worse.

He was referred to me after seven months of this continued trouble. Examination showed a muscular, well-built man of some 140 lb., with no extra fat. He wore a back brace and walked carefully, as though protecting his back against jar. He could flex forward almost normally and without complaint of pain. Extension of his back developed pain slightly above and internal to the sacro-iliac joint. Lateral flexion and rotation to the left caused definite pain. The thighs could be flexed upon the abdomen equally, yet extreme flexion of the left thigh gave pain. Kernig's sign was not present and there was no sciatica. Examination of the back showed no deformity. Palpation with the finger tips showed a sense of tenseness or spasticity in

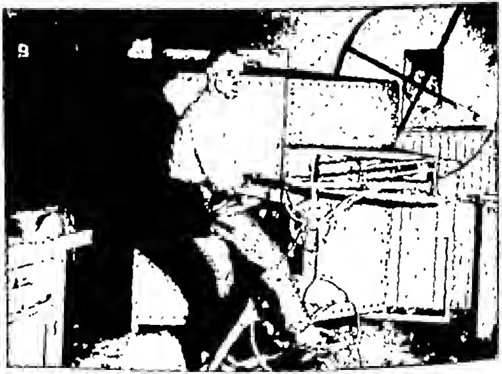

FIG. 16.—Photograph of C. F. (Case 11) working in the occupational therapy department; using a jig saw.

the muscles of the left side as compared with those of the right, and this could be increased by movements which caused pain. Tender or sensitive nodes could be felt in the muscles of the left side of the low back.

The x-ray showed the sacralized fifth lumbar vertebra with the greatly widened transverse process on the left as shown in Figure 2. It was possible to see a slight articulation between the process and the sacrum.

Diagnosis was a bruise of this anomalous articulation with a traumatic arthritis plus contraction of the ligaments, muscles, and aponeurosis from prolonged immobilization and disuse.

Treatment consisted of placing this patient in the hospital where he rested in a firm, straight bed and was given continuous heat and gentle daily mas-

held firm and almost rigid, knees straight, and feet straight or toed in. A full-length mirror should be installed in the treatment room, and these patients should be drilled in front of it until they have this proper posture firmly fixed in mind. In the presence of strained or sprained back the acute condition must be relieved, and graduated exercises leading up to the postural exercises should be used (Cole and Brown, Vol. III).

Flatfeet

Flatfeet may be the basis of certain faulty postures or of imbalance underlying the painful back. With this as a predisposing cause a slight injury may excite the back trouble.

I have had several cases of persistent disability from alleged injuries referred to me for reconstructive treatment whose condition was relieved by massage and exercise of the feet combined with rest. A very good exercise for the feet is walking on the toes in a pigeon-toed position. Flatfoot is considered at length by Lewin (Vol. II).

Osteo-arthritis

Osteo-arthritis of the spine is so frequently found associated with an injury that one's ingenuity and judgment are taxed to determine whether the injury plays a part in the trouble or whether it is solely due to the arthritis.

Etiology.—Injuries to the joints of the back can produce an acute traumatic arthritis just as can injuries in other joints. Repeated traumas in time may lead to a hypertrophic arthritis. Probably a severe injury, such as a compression fracture, may be accompanied with some definite damage to the articular surfaces, and such a joint may more readily be subject to arthritis.

Unquestionably when the "spring" is gone from the feet and one becomes conscious of pounding his back joints when walking on a hard pavement, one is in a potential position to develop a type of traumatic arthritis. The repeated trauma to the back which is the result of hard work in faulty positions, as in mining, in time results in osteo-arthritis.

Overlifting, a sudden twist, the jerk of a train, a fall, or a similar mild trauma in such an individual will result in a disabling back condition. The patient frequently has never been disabled and has never been conscious of the arthritis. To convince him that he has a diseased condition and that the injury played no part in it is impossible. In fact, one must in fairness say that in the majority of these cases the injury, although trivial, aggravated or excited a latent arthritis.

Treatment.—The treatment of arthritis is dealt with at length in other chapters. These cases, however, must be put at rest during the acute stage and heat should be applied to relieve the pain. Dry heat, such as an electric pad, a baker, or an infra-red lamp, is best. Traction

I have had one case of fracture of the fourth spinous process where the signs and symptoms were quite similar to a sprain-fracture about other joints. Rest, immobilization in a firm, straight bed, with heat, massage, and graduated exercises after four to six weeks, were the forms of treatment followed.

Injuries of the Coccyx

Congenital anomalies are common in this bone. Fractures and dislocations of the coccyx are exceedingly difficult to diagnose. The x-ray of the normal coccyx in a large number of cases shows all kinds of variations in the position of the coccyx. Thus Potter states that he will seldom give an opinion relative to a dislocation of this bone. Fracture lines may occasionally be demonstrable.

The history of a fall or blow directly on the coccyx followed by acute symptoms is far more suggestive. Old cases of long standing with painful coccyx dating from such an injury often develop such rare and obscure symptoms that one is prone to say that the patients are neurasthenic.

Early manipulation of the coccyx with the index finger of one hand in the rectum and the finger of the other hand pressed against the back of the coccyx will sometimes give miraculous results.

All cases of continued pain and especially pain on movement or after sitting for any length of time should receive careful physical therapy before operative removal of this bone is considered. Heat (in this case, heat in the form of diathermy) will usually relieve the pain temporarily. Heat should be followed by massage. After a few treatments of this nature, manipulation of the coccyx should be done to see if the painful condition cannot be permanently eliminated. After several attempts have failed, then the surgeon is justified in considering operative removal. Physical therapy, especially heat and massage, should follow the operation.

Postural Conditions Associated with Injury

Faulty posture, especially the relaxed type—the head carried forward, the neck markedly flexed, a somewhat hollow chest, a dorsal round back, the "pot belly" with relaxed abdominal muscles, and a marked lordosis in the lumbar region, knees slightly bent, and feet turned outward—is characteristic of weak back. When such an individual suffers even a trivial injury, he develops a strained or often sprained back that is very persistent.

Any treatment of these cases that does not aim at the correction of the faulty posture is usually doomed to fail. The strain or sprain must be treated as already outlined.

In addition, these patients must be drilled to hold up their heads, chin draw[illegible] slightly in, back erect, abdominal muscles sucked in and

Heat, either moist or dry, and even diathermy may be used to aid in the absorption of these blood collections. Later massage consisting of gentle stroking in the direction of the venous flow will be of great assistance. Seldom is it necessary to incise and evacuate the large blood clot, although in certain cases this may be advisable.

Burns

Burns of the back are difficult to treat because they are often accompanied by burns on the abdomen and it is hard to keep the patient off his back. It is equally hard to prevent soiling and infection in the low back burns.

Tannic acid treatment may be indicated. Often these cases do better under open air and light treatment. The patient is placed on his abdomen, a sterile tent is made over the bed, and heat is applied to the back by a large electric light bulb. The temperature in the tent is maintained at 76 to 80° F. (24.4 to 26.6° C.). Such a patient can be lifted from the bed and suspended in a tub of warm water to soak away the crusts. This form of hydrotherapy is dealt with by Blair and Brown (Vol. II). It can be repeated two to four times per day. Ultraviolet treatment of the scars followed by massage is indicated if excessive scarring occurs.

Sensitive Nodes

In many cases of old back injuries as well as in persistent back pain from posture, disease, or other cause, we frequently find on careful, gentle palpation small, slightly movable tender nodes which seem to lie in the muscle or fascia. These have been called "fibrositic deposits," "myofascitis," and by similar descriptive names, indicating that they are changes in the muscle or fascia.

For several years I have noted and have called my colleagues' attention to small sensitive nodes under the skin in many of these chronic back cases. A peculiar phenomenon in connection with these nodes is their tendency to disappear on persistent palpation. Thus one feels the node, moves it around, palpates it for a time, and then it seems to disappear. I have called one or two of my associates to examine such a node. Perhaps by the time the third doctor starts to feel it the node is no longer present. Technicians have noticed these "knotted muscles" disappear under their massage. A similar phenomenon is often noticed in palpating a spastic colon. After it has been rolled several times under the examining finger the bowel seems to relax and can no longer be palpated. A more acute condition is seen in "muscle cramp" when in the calf of the leg especially, a hard knot, excruciatingly painful, appears. It is often relieved only by massage or by bearing weight upon the leg, when it suddenly disappears.

is often a useful measure. Very gentle stroking massage should be given daily. Only such exercises as flexing and extending the lower legs are all these patients can stand in acute cases, but as the acuteness subsides, the force of the massage is increased, and assisted exercises, such as helping the patient to lift the shoulders or placing the hand under the buttocks and having the patient contract the muscles as though lifting his back from the bed, are added. Great attention must be paid to the bed during this stage. It should not sag or cause faulty posture positions to develop. As soon as possible, bring flexion and lateral motions and extension into the exercises and continue the heat and massage. *Diathermy* may now be found an excellent method of giving the heat. That method of applying heat which gives the greatest relief of pain is best. Many methods may have to be tried, but the treatment must be persisted in until the patient has again returned to that painless, quiescent stage of arthritis which existed prior to the injury.

General treatment must not be neglected. Every arthritic patient has a pitcher of lemonade at his bedside and he is urged to drink at least two quarts in the 24 hours. Aspirin, sometimes combined with pyramidon, is used to relieve pain. Effort must be made to build up the general condition of the patient.

A certain number of these cases will not be relieved by this régime. Immobilization of the back in a specially made back brace may be the only means of allowing such a patient to become ambulatory. However, before the back is immobilized in a brace, every effort should be employed to prevent the contraction and disuse of the muscles, the thickening of the joint capsules and ligaments following the synovitis of the acute condition, and the painful stiff back. Certain cases will gradually become quiescent in a brace and the brace can then be eliminated, but many arthritic patients who must wear a brace will be semi-invalids.

Tuberculosis or Malignancy

Injury may be the first indication of *tuberculosis*, a malignancy (primary or usually metastatic), or other diseased condition of the spine. The treatment of these conditions is dealt with in other chapters.

Injuries to Soft Tissues of Back

Hematomas may develop in the back and may be of extremely large size and quite disabling. I have seen several cases of fractures in the lumbar region and two with fractures of the pelvis develop large hematomas in the back and flank. In two of these cases aspiration of the mass removed several hundred cubic centimeters of bloody serum. In one case the aspiration had to be repeated three times at intervals of two and five days.

Heat, either moist or dry, and even diathermy may be used to aid in the absorption of these blood collections. Later massage consisting of gentle stroking in the direction of the venous flow will be of great assistance. Seldom is it necessary to incise and evacuate the large blood clot, although in certain cases this may be advisable.

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Etiology.—One conjectures concerning these more chronic sensitive nodes which are felt in the lower back and are often present in the muscles of the back of the neck and frequently in the lower extremities. Is it not possible that they are spastic muscle bundles or muscle fibers and that all these phenomena are more or less due to the same causes? We see spastic colons in nervous, highly strung, tense individuals. Often there is a history of worry, phobias of various kinds, and fatigue due to all work and no play. There is bowel dysfunction which may cause the local fatigue. In the acute muscle cramp, fatigue is often present, and it is very common in the pregnant woman who is heavy on her feet. Hunters sometimes get it at night after a hard day's tramp in the woods. Imbalance due to flatfoot or changing from high heels to low heels may cause it. Frequently it is noted after long periods of stress and great fatigue.

In the more chronic, localized sensitive nodes in the injured back we have the fatigue of dysfunction in the muscles, the worry and nervousness over the condition, the fatigue of holding the back more or less rigid, and the lack of exercise; often the patient is a highly tensed individual.

Usually the condition is ascribed to a toxic or infectious origin and is designated as a myofascitis. It is mentioned as an indication for colonic flushing to rid the body of these toxic substances, but in my opinion there is real evidence which points to the possibility that this condition is due to fatigue poisoning or the dysfunction of the local innervation to a small muscle bundle due to local or general fatigue.

Fatigue.—Fatigue is thought of in connection with hard work. "Dead tired" at night from a hard day's work involving much muscular activity is a healthy condition, as a rule, but fatigue that comes from great tension as seen in the high-powered executive, or in the tensed, nervous woman worn out by the cries of the baby, the fussing of the older children, and the housework, or fatigue due to pain, discomfort, holding one's back rigid to get a little respite from pain—all these continued over days and weeks can be a very unhealthy type of fatigue.

Individuals with fatigue of this kind can develop a spastic colon or backache. The colon can be palpated usually in the left lower quadrant. The sensitive nodes herein described can likewise be palpated in the case of backache. Cure the one by rest and change of habits, release the tension, and establish healthy exercise, and you usually cure the other. Perhaps colonic flushings help, but I have seen many cured without them by developing a health régime, correcting faulty posture, relieving the causes for worry at home or at work, and applying heat and massage to the sensitive area in the back of the neck or low back.

Eight years ago I developed a lame back and pain down my left sciatic nerve. I was treated with intermittent heat and massage with

only temporary relief. Finally I had my teeth x-rayed and took the films to Dr. Thomas Gilmer, positive that two of my teeth had better come ont. Dr. Gilmer was on the same hospital staff and knew that I had been working very hard and under great tension. He asked relative to my last vacation and how much exercise and play I was getting. It had been a year since I had had a short vacation and I had almost forgotten how to play or exercise. Instead of pulling the teeth he gave me a valuahle talk on fatigue and fatigue poisoning from prolonged high-pressure work and suggested that a vacation would cure the back and leg trouble. The next week, accompanied by my wife, I started for Seattle. The first morning we left our sleeper for 15 minutes at Minneapolis and walked up and down the platform. I felt very peppy and finally my wife asked concerning my backache. To my surprise both the backache and the tendency toward sciatica had disappeared and never returned except years later when I again became "tensed up" with overwork. This was not neurosis—it was simply relaxation and getting rid of chronic fatigue.

Let an individual prone to these sensitive nodes sustain an injury ever so trivial and frequently he develops a chronic traumatic back; or let one suffer a sprained back and go for weeks with the back held rigid by a protective muscular tension or lie in bed without exercise or massage aod he will develop these sensitive nodes. Thus they play a very important rôle both in diagnosis and in treatment.

Diagnosis.—When located in the back of the neck, they are felt just lateral to the cervical spines and are usually superficial, although deep palpation may be necessary to feel them. At times they occur in the supraspinatus muscle or over the scapula. They are often mistaken for glands. They are sensitive to pressure, are usually accompanied with a sense of soreness or slight stiffness in the neck, and often cause a low-grade occipital headache. They usually soften and disappear under massage hut may return again in a short time. A mild form is that found in tired business men who notice the tense, sore feeling in the neck after going to bed and who are frequently relieved when the wife rubs the back of the neck for a short period.

When these occur following injury or in cases of long illness, regular periods of application of heat followed by at feast 30 minutes of rhythmic, stroking massage and then kneading massage will relieve the condition. The treatment must be persisted in until the relief is permanent.

In the small of the back these sensitive nodes are most frequently felt in the gluteal regions just outside the sacro-iliac joints; in the erector spinae muscles, near their outer borders and opposite the fourth and fifth lumbar vertebrae or just lateral to the spinous process of the first lumbar vertebra. Often a sensitive area is felt near the sciatic notch and similar sensitive nodes are usually present in one or both legs. The commonest site in the leg is at the upper margin of the calf about one inch from the inner side and two inches below the head of the tibia.

Etiology.—One conjectures concerning these more chronic sensitive nodes which are felt in the lower back and are often present in the muscles of the back of the neck and frequently in the lower extremities. Is it not possible that they are spastic muscle bundles or muscle fibers and that all these phenomena are more or less due to the same causes? We see spastic colons in nervous, highly strung, tense individuals. Often there is a history of worry, phobias of various kinds, and fatigue due to all work and no play. There is bowel dysfunction which may cause the local fatigue. In the acute muscle cramp, fatigue is often present, and it is very common in the pregnant woman who is heavy on her feet. Hunters sometimes get it at night after a hard day's tramp in the woods. Imbalance due to flatfoot or changing from high heels to low heels may cause it. Frequently it is noted after long periods of stress and great fatigue.

In the more chronic, localized sensitive nodes in the injured back we have the fatigue of dysfunction in the muscles, the worry and nervousness over the condition, the fatigue of holding the back more or less rigid, and the lack of exercise; often the patient is a highly tensed individual.

Usually the condition is ascribed to a toxic or infectious origin and is designated as a myofascitis. It is mentioned as an indication for colonic flushing to rid the body of these toxic substances, but in my opinion there is real evidence which points to the possibility that this condition is due to fatigue poisoning or the dysfunction of the local innervation to a small muscle bundle due to local or general fatigue.

Fatigue.—Fatigue is thought of in connection with hard work. "Dead tired" at night from a hard day's work involving much muscular activity is a healthy condition, as a rule, but fatigue that comes from great tension as seen in the high-powered executive, or in the tensed, nervous woman worn out by the cries of the baby, the fussing of the older children, and the housework, or fatigue due to pain, discomfort, holding one's back rigid to get a little respite from pain—all these continued over days and weeks can be a very unhealthy type of fatigue.

Individuals with fatigue of this kind can develop a spastic colon or backache. The colon can be palpated usually in the left lower quadrant. The sensitive nodes herein described can likewise be palpated in the case of backache. Cure the one by rest and change of habits, release the tension, and establish healthy exercise, and you usually cure the other. Perhaps colonic flushings help, but I have seen many cured without them by developing a health régime, correcting faulty posture, relieving the causes for worry at home or at work, and applying heat and massage to the sensitive area in the back of the neck or low back.

Eight years ago I developed a lame back and pain down my left sciatic nerve. I was treated with intermittent heat and massage with

only temporary relief. Finally I had my teeth x-rayed and took the films to Dr. Thomas Gilmer, positive that two of my teeth had better come out. Dr. Gilmer was on the same hospital staff and knew that I had been working very hard and under great tension. He asked relative to my last vacation and how much exercise and play I was getting. It had been a year since I had had a short vacation and I had almost forgotten how to play or exercise. Instead of pulling the teeth he gave me a valuable talk on fatigue and fatigue poisoning from prolonged high-pressure work and suggested that a vacation would cure the back and leg trouble. The next week, accompanied by my wife, I started for Seattle. The first morning we left our sleeper for 15 minutes at Minneapolis and walked up and down the platform. I felt very peppy and finally my wife asked concerning my backache. To my surprise both the backache and the tendency toward sciatica had disappeared and never returned except years later when I again became "tensed up" with overwork. This was not neurosis—it was simply relaxation and getting rid of chronic fatigue.

Let an individual prone to these sensitive nodes sustain an injury ever so trivial and frequently he develops a chronic traumatic back; or let one suffer a sprained back and go for weeks with the back held rigid by a protective muscular tension or lie in bed without exercise or massage and he will develop these sensitive nodes. Thus they play a very important rôle both in diagnosis and in treatment.

Diagnosis.—When located in the back of the neck, they are felt just lateral to the cervical spines and are usually superficial, although deep palpation may be necessary to feel them. At times they occur in the supraspinatus muscle or over the scapula. They are often mistaken for glands. They are sensitive to pressure, are usually accompanied with a sense of soreness or slight stiffness in the neck, and often cause a low-grade occipital headache. They usually soften and disappear under massage but may return again in a short time. A mild form is that found in tired business men who notice the tense, sore feeling in the neck after going to bed and who are frequently relieved when the wife rubs the back of the neck for a short period.

When these occur following injury or in cases of long illness, regular periods of application of heat followed by at least 30 minutes of rhythmic, stroking massage and then kneading massage will relieve the condition. The treatment must be persisted in until the relief is permanent.

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Symptoms.—The signs and symptoms caused by these nodes in addition to their sensitiveness are radiating pains, or more often a slight discomfort with restlessness. The patient moves his legs frequently, "can't hold them still," and at night when he is falling to sleep the leg will jerk spasmodically.

Treatment.—The treatment as already indicated is general and local. Remove the factors of tenseness, nervousness, and fatigue, and develop healthful exercises and relaxation. Improve elimination. Locally the condition must be treated by heat, massage, and graduated exercises. Often diathermy is found very beneficial, as it relieves the pain, causes a local congestion, and, when followed by massage, will often cause very persistent sensitive nodes to disappear. In place of massage, the sinusoidal current or a strong vibrator may be used. I know many taut business men who, suffering with this condition in the neck or shoulders, have their barber use a vibrator on the part. The use of a galvanic current with the needle inserted directly into the node has been advocated as well as acupuncture.

Traumatic Neuroses

Definition.—A pure neurosis is one in which all the signs and symptoms are based upon a functional condition in contradistinction to those conditions with an organic background. I believe it is impossible always to rule out the influences which certain minor organic conditions play in the neurosis. This is certainly true in traumatic neuroses.

Etiology.—Traumatic neuroses may develop in spite of the fact that the trauma was trivial or nil and that absolutely no demonstrable organic lesions resulted from the accident. This type of neurosis is often seen in patients who were on the edge of a terrible accident but escaped without a scratch. In others the organic lesions, the result of an accident, have been cured, but a functional neurosis has developed during the period of disability and continues as the sole cause of incapacity. In this latter group the cause of the neurosis may be the nature of the accident; the nature of the trauma; some statement made by the attending physician which exaggerates the importance of the injury in the patient's mind; statements made by the family, the nurse, or often an interested lawyer, which exaggerate the importance of the injury in the patient's mind; or the true compensation neurosis where the desire for a good settlement causes the patient to dwell upon his injury until its importance has become magnified in his own mind. Occasionally the desire for sympathy or the desire for revenge—for example, when a patient wishes to prove some other physician wrong—and similar mental impulses are behind the neurosis. Finally, there is the third group in whom the physician fails to find the evidence of organic injury and yet the patient continues to have disability. Always

in this group some remnant of the organic lesion is still present which forms the underlying basis of the neurosis. Elsewhere in this chapter I have referred to this type as the "misunderstood neurosis." Diligent search on the part of the physician is necessary to reveal the underlying organic condition.

As the years go by I am positive that many of us are too prone to label our patient as a case of true neurosis when the real condition is a combination of some traumatic organic lesion with a superimposed neurosis.

Classification.—In prescribing or practicing physical therapy in functional conditions, it is imperative to classify these cases in one of the following groups:

GROUP I: TRAUMATIC NEUROSIS: NO ORGANIC INJURIES; PURELY A FUNCTIONAL CONDITION.—In these it is seldom wise to let the patient feel that he has an injury which must be treated. If you dismiss such a case with the statement, "There is absolutely nothing wrong with you," he will usually go away disgruntled. Often instead of helping him you have made his condition worse.

In cases of alleged back injury in this group one usually finds that such patients have fallen into faulty postures due to alleged pain; or have become soft and flabby due to lack of work over a long period of months; or have simply fallen into faulty habits of holding the back stiff, walking with a limp, or exhibiting organic lesions which do not exist.

As a rule it is wiser in this group to gain the patients' confidence and then gradually to remove from their minds the fixed idea of organic injury—by various types of explanatory talks pointing out that instead of being "scared to death" by an accident that might have been extremely serious they were scared into a back disability. At this stage one can usually tell them frankly that absolutely no organic injury resulted from the accident, but that the injury was all mental and that the long-continued disuse of the back with gradually developing faulty postures or stiffness is the sole cause of disability. During this period of gaining their confidence, physical therapy (which is only another name for common sense handling of the case) should be administered. It may be given by the physician or some member of the family, but as a rule it can best be administered by a trained technician under the direction of the physician. Physical therapy should consist of a certain amount of massage and large amounts of retraining exercises. Reëducation of joint function is just as important in the numerous joints of the back as it is in the hysterical knee joint; therefore all exercises should be directed toward the reëducation of these joints, the obliteration of the stiff back, the correction of faulty posture and functional limps, and the gradual hardening of the patient.

Success in curing this type of neurosis depends upon gaining the

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When the cases in this group are due to exaggerated statements by the relatives or by some interested lawyer, one must make sure that the desire for recovery is greater than the desire for compensation. If the former is the case, the patient should be handled as just described. However, if the desire for compensation, sympathy, or revenge is the underlying motive for the neurosis, any form of treatment may only enhance the functional condition.

Cases of compensation neurosis are alleged by some to be very rare, while other writers place this as the commonest cause for neurosis. It is my opinion that these two views depend upon the number of compensation cases being handled by the various writers. An industry or insurance company that adopts a liberal attitude toward compensation cases usually has fewer cases of compensation neurosis among the injured than does a company which has a hard-boiled attitude.

Back cases which are purely compensation neuroses seldom yield to physical therapy. An early settlement of the case usually results in a cure of the condition.

Group III: Traumatic Neurosis: Remnants of the Organic Lesion Remaining with a Superimposed Neurosis.—In this group, careful search, when applied to back cases, will usually reveal the traumatic arthritis, the thickened ligaments, the contracted muscles, the thickened aponeuroses and adhesions, the sensitive nodes, and similar conditions which are the aftermath of the original injury. The neurosis must be treated by gaining the confidence of the patient as already detailed.

Physical therapy in the form of heat, massage, exercise, manipulation (often under anesthesia), occupational therapy, and similar methods aimed at overcoming obscure but demonstrable organic lesions will usually cure this type of neurosis. These patients, usually misunderstood and neglected, are the ones who respond most readily to, and who are most grateful for, treatment.

The dictum that you "can rub more trouble into a neurotic patient *in* an hour than you can rub out in a month" is true in a certain number of these functional neuroses. Careful classification of the neuroses, however, will reveal a large number in whom physical therapy is definitely indicated. The following case is an excellent example of a traumatic neurosis in a back injury:

Case 12.—J. A., a carpenter, aged 42, married and with three children, while working in a small community in southern Illinois in 1923 fell from a building a distance of 28 ft., injuring his back. X-ray facilities were not available to verify the diagnosis of "broken back," which was made in this case. He was treated in his home, lying prone in bed for approximately six months. He was finally awarded a total disability by the compensation board. He was referred to the author 16 months later to see whether anything could be done to decrease his per cent of disability. At the first examination the patient had a resigned, feeling-sorry-for-himself expression on

patient's confidence and refitting him for work. In some this can be accomplished in two weeks; in others it may take months. It is far better to persist in the treatment than to turn these patients loose as neurotics with continued disability. Frequently they will leave the physicians and drift into the hands of cultists who will cure them simply because they have more time and patience and a better understanding of the psychology involved.

Group II: Traumatic Neurosis: Organic Lesions Cured but Disability Persisting Due to the Neurosis.—In back cases in this group when the neurosis is due to an exaggeration of the seriousness of the original trauma or the seriousness of the original accident, such patients should be handled as suggested under Group I.

When the back neurosis is due to some erroneous idea or to an exaggeration of the seriousness of the injury, often the result of some unguarded statement made by the attending physician, the idea must be wiped out before the neurosis can be overcome.

If a physician tells the patient that he has a "broken back" when the lesion is a simple linear fracture of a transverse process, a neurosis frequently develops which prolongs the disability for months and sometimes years after the simple linear fracture has healed. Sometimes during the acute stage the patient will complain of his suffering or of the length of treatment; the physician, to justify his treatment, sometimes replies, "You are lucky to be alive," or "It will take a long time to get you well and you will never be completely well," or, "You will be permanently disabled." Unguarded statements such as these form the basis of many traumatic neuroses and, of course, should always be avoided.

Recently I saw a patient suffering from a traumatic neurosis which was solely due to the fact that his family physician had written a letter at the request of the patient, stating that his patient had his skull fractured and was therefore unfit for jury service. Subsequent x-rays failed to show the skull fracture. The patient had completely recovered from his injury within three weeks and was ordered back to work by this physician. Instead of going to work he developed symptoms of a true neurosis. There were absolutely no organic findings. The underlying cause of the neurosis was the patient's inability to understand why his family physician had written that he had a skull fracture, then later told him that he did not have a skull fracture and continued to insist that he was able to go to work.

Physical therapy is indicated in this class of cases when stiffness of the back joints, thickened ligaments, contracted muscles, thickened aponeuroses, faulty postures, functional limps, and general softening indicate the need of heat, massage, and exercise. The administration of some simple form of physical therapy, thereby expressing the physician's interest in the case, combined with the physician's supervision, will go far toward overcoming this type of neurosis.

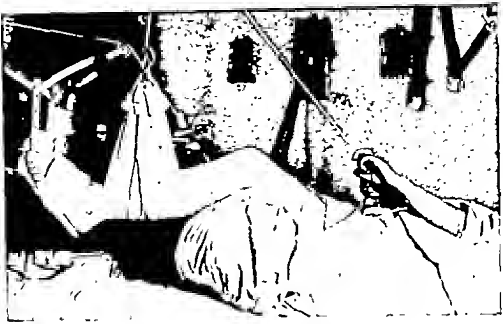

FIG. 17c.—Same as Fig. 17b showing method of securing knee flexion.

FIG. 18.—Case of F. B. six years after fracture of 1st lumbar vertebra, with immediate paralysis due to compression of the cord and transfixion of the cord by splinter of bone transfixion. Laminectomy performed two hours after injury. Patient received physical therapy and protection against foot drop continuously immediately following the operation. Within a year he was walking.

FIG. 17a.—Case of fractured 12th dorsal vertebra with complete paralysis following damage to the cord and complicated by fracture of the right femur. The femur is being treated by skeletal traction. Observe splints on each foot to prevent foot drop. Patient received massage, muscle-training exercises and active exercise throughout her confinement in bed.

FIG. 17b.—Patient exercising her paralyzed left leg by means of a sling, pulley and rope.

Fig. 19b.—Patient receiving physical therapy and muscle-training exercises.

Fig. 19c.—Same as Fig. 19b. Complete recovery after two months. Bullet not removed.

FIG. 191.—X-ray of bullet wound of spine with hemorrhage about cord followed by extreme hyperesthesia and paralysis of left leg.

his face; he stood with his feet a little apart and his back flexed about 10°; on walking he took steps from 10 to 12 in. long and progressed very slowly; movements of the back were slow and restricted, the patient bending forward only about 25° and not being able to straighten his back completely; he could raise his arms only slightly above a right angle to his body. Physical and x-ray examinations were negative for organic disease. There was no sign of a fractured vertebra. Functional tests showed variations in pain and tender points along the spinal column, with atypical areas of anesthesia. The observations were definitely those of a person with traumatic neurosis.

The patient was admitted to St. Luke's hospital and was assigned to a regular routine of treatment, consisting of periods of heat, massage, exercise, tub baths, and rest. In addition to this he was assigned to the occupational therapy workshop for two hours a day at first, but the time was increased daily. After about the fourth day it was noticed that the patient was spending all his spare time in the workshop. He was asked to make a special splint for one fellow patient and to make the peg leg portion of a temporary artificial leg for another patient. He was so handy with tools that he was soon acting as an assistant to the technician.

At the end of two weeks the patient was walking with a normal stride, could bend over and touch the floor, could stand erect, and could raise his arms over his head. It was carefully explained to the patient that he had never had a broken back but that his trouble was all due to nervousness which he had overcome during these two weeks in the hospital, and he was discharged. Unlike many persons with neuroses, he was extremely happy over his recovery and immediately returned home and went to work. Although the surgeon and the physical therapist were of some aid in his recovery, the practical application of occupational therapy should receive the chief credit.

Conclusions

I have contributed this chapter as a surgeon confronted with a great many back cases and especially old back injuries which have failed to respond to other treatment. I am not a physical therapist. When physical therapy is necessary, it is administered by qualified technicians under the direction of my associate, Dr. J. S. Coulter, but I constantly supervise the case.

I have found as the most valuable adjuncts to the surgical treatment of these cases various kinds of heat, various types of hydrotherapy, and, above all, massage and exercise. The exercise should be graduated from the simple contraction and relaxation of muscles while the patient is lying in bed to movements involving flexion and extension and lateral motion of the back; exercises involving lifting and carrying; the use of various kinds of apparatus, such as a rowing machine; and finally, to the exercises involved in gradually increasing amounts of work, referred to as occupational therapy.

In this chapter I have not dwelt in great detail upon the methods advocated for administering the various forms of physical therapy. For details concerning the *modus operandi* of the various methods, the reader is referred to the chapters on technic, Volume I.

FIG. 10.—Compression fracture of 7th dorsal vertebra treated by hyperextension with body cast applied in position of hyperextension. The back of the cast cut out to allow massage of the back muscles. Patient was taught to shrug her muscles for active exercise. Complete recovery in nine weeks

CHAPTER SEVENTEEN

PHYSICAL THERAPY IN DEFORMITIES OF THE SPINE

R. B. DILLEHUNT, M.D.

Perhaps in no instance is the adage "an ounce of prevention is worth a pound of cure" more applicable than in potential or incipient deformities of the spine. In joints of the extremities, even when great deformity has been established, surgical and mechanical measures are available which enable the most spectacular alleviation or correction. But in severe deformities of the spinal structure which have once become confirmed and fixed, with all the associated somatic and visceral pathology, complete correction is practically never accomplished and even improvement is often almost unattainable. The difficulty is due to the anatomic and physiologic complexity of the spinal bones, joints, and musculature, and to the relative inaccessibility of the spinal column and thorax to the application of corrective measures in the form of apparatus dependent upon pressure for their corrective influence. In other words, since one cannot "get hold of" the spine with hands or apparatus to the degree that obtains with reference to the knee or elbow, manipulative or corrective influences must be exerted less directly and therefore less effectively. When one experiences the difficulty encountered in correcting an ordinary clubfoot in a child, in which the foot and leg can be grasped powerfully in the hands and are seemingly under the command of the operator, it can readily be appreciated how relatively little direct force one can exert upon a spinal deformity when one's efforts are applied to the pelvis, thorax, and axillae.

It is therefore of the greatest importance that frequent examination be made of growing children to detect potential deformity and that preventive measures be instituted early. So insidious is the development of spinal deformity, not only in children as a result of congenital, paralytic and postural causes, but in adults incidental to postural, mechanical, or arthritic influences, that the orthopedic surgeon seldom has opportunity to boast of having prevented deformity; but he is constantly confronted with the problem of attempted correction, which often results in no more than preventing it from progressing to a more severe degree. Since there are other chapters which deal with the principles of the prevention of deformity, only the common types of deformity of the spine and the physical therapeutic measures designed for their alleviation or cure will be discussed here.

Finally, I have treated in considerable detail the classification, etiology, and diagnosis of back injuries in order to illustrate and stress the importance of a thorough understanding of the back condition before attempting any physical therapy measures.

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Apart from actual operative surgical procedures, the entire treatment of spinal deformity is "physical therapeutic." The exertion of influence by push or pull or manipulation or traction, whether from within by muscular effort or from without by manual or mechanical effort, is physical therapy; hence one cannot exclude those measures applied by the surgeon and intelligently discuss those commonly delegated to the trained physical therapist because they are reciprocal parts of the same rationale.

There are numerous deformities of the spine of congenital origin, such as spina bifida, synosteosis of vertebrae, cervical rib, variations in number and shape of spinal segments, and other embryologic aberrations which may or may not produce deformity but which in any event are not amenable to physical therapy and are hence not discussed. Moreover, diseases of the spine, such as tuberculosis, syphilis, and other granulomatous infections, as well as osteomyelitis, neoplasms, and trophic disorders, are not the subject of physical therapeutic ministration except in so far as they may produce deformity and are accordingly dealt with in other sections. Similarly, traumatic lesions comprise a special subject. Hence this chapter deals with deformities of the spine which may be considered to have been theoretically preventable and are capable of improvement by mechanical means, whether of constitutional, static, paralytic, or arthritic origin.

Anatomic and Physiologic Considerations

Effective treatment of spinal deformity must be based upon a knowledge of the grosser and simpler principles of the structure and function of the spine. Although there are marked differences in structure and form between the spine of the infant, child, adolescent, and adult, these differences do not materially modify the principles of treatment except in so far as the progressive decrease in resiliency and flexibility with advancing years makes treatment less and less effective; therefore, for the sake of brevity, variations with the age of the patient will not be enumerated.

In general the spine is considered as that part of the vertebral column above the sacrum. It comprises about one-third of the length of the body and is composed of 24 segments, the upper seven being designated as the cervical, the eighth to the nineteenth inclusive as the dorsal, and the lower five as the lumbar. The first cervical vertebra articulates with the base of the skull, and the last lumbar with the sacrum, which is solidly fixed between the two iliac bones, forming with them the unyielding pelvic ring. The sacrum represents the base of the spine, being wider and thicker than any other vertebral segment, and the bony mass tapers gradually in anteroposterior, lateral, and axial dimensions from the sacrum upward, so that the cervical vertebra is smaller in all diameters than the dorsal and the dorsal is

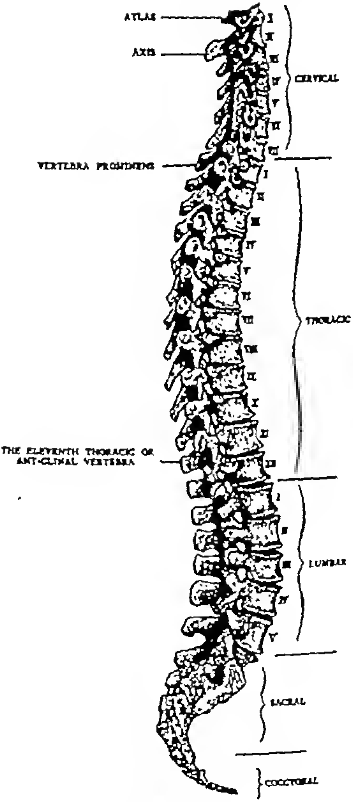

FIG. 1.—The spine. (Lateral view.)

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smaller and less massive than the lumbar; hence the column is pyramidal, with its base below (Fig. 1).

Each segment or vertebra is in the form of an irregular osseous ring with a circular body flat above and below, forming an anterior portion, and a posterior portion known as the arch, made up of the laminae, spinous, transverse, and articular processes. The anterior and posterior portions are joined on each side by the short pedicle to form the ring (Figs. 2 and 3). Thus the spinal column is formed of a series of superimposed rings, each articulating with the one above, both in its an-

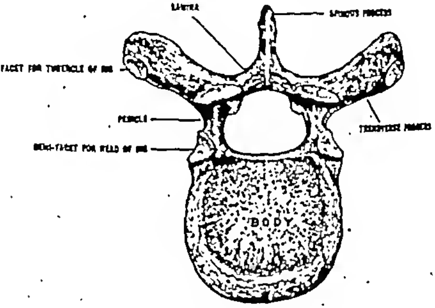


Fig. 2.—A thoracic vertebra. (Morris.)

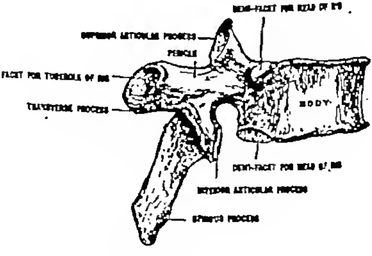


Fig. 3.—A thoracic vertebra, side view. (Morris.)

terior and posterior portions. The bodies of the vertebrae are separated from each other by an intervening cushion of fibrous elastic tissue, the intervertebral disc, which fills the entire intervening space and is attached firmly to the vertebral body. The disc projects a little beyond the rim of the vertebral body. The periphery of the disc is firm and fibrous, while in its center is a soft and movable fibrous mass, the nucleus pulposus, occupying little less than one-half the total area of the disc (Fig. 4). The discs vary in shape and thickness in different regions of the spine. In the cervical region they are thicker in front than behind, thus necessitating the normal anterior convexity of the cervical spine. Similarly in the lumbar region they are a little thicker

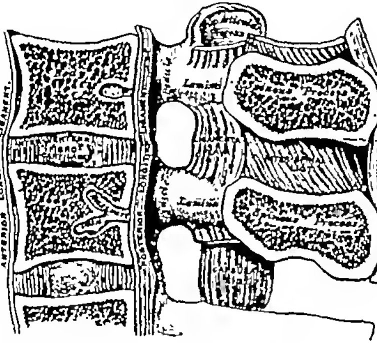


FIG. 4—Median sagittal section of two lumbar vertebrae and their ligaments. (Gray.)

anteriorly, causing anterior convexity, and their general thickness here is greater than their cervical or dorsal thickness. In the dorsal region they are more nearly symmetrical, and the backward curve of the dorsal spine is due more to the shape of the vertebral bodies and to the necessity of its conformation in connecting a curve above and below. The discs comprise 25 per cent of the total length of the spine, hence in the aged in whom they become narrowed the spine is shortened and bent forward throughout.

The posterior portion of each vertebra articulates on each side with the one above by the articular processes, producing joints which, in the cervical region, are flat and slope backward and downward at an angle

smaller and less massive than the lumbar; hence the column is pyramidal, with its base below (Fig. 1).

Each segment or vertebra is in the form of an irregular osseous ring with a circular body flat above and below, forming an anterior portion, and a posterior portion known as the arch, made up of the laminae, spinous, transverse, and articular processes. The anterior and posterior portions are joined on each side by the short pedicle to form the ring (Figs. 2 and 3). Thus the spinal column is formed of a series of superimposed rings, each articulating with the one above, both in its an-

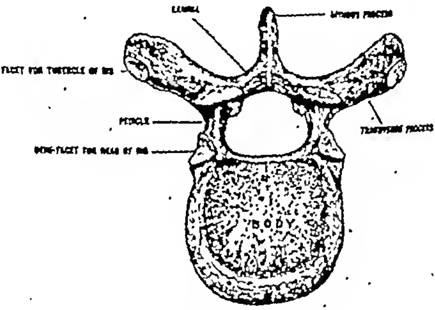


Fig. 2.—A thoracic vertebra. (Morris.)

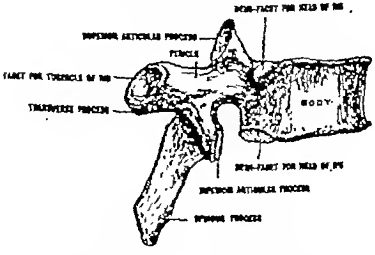


Fig. 3.—A thoracic vertebra, side view. (Morris.)

importance in disordered states. For detailed study of the musculature of the spine, thorax, and abdomen, all of which must be regarded as controlling the spinal movements and stability, the reader should refer to standard works on anatomy. For the purpose of this discussion

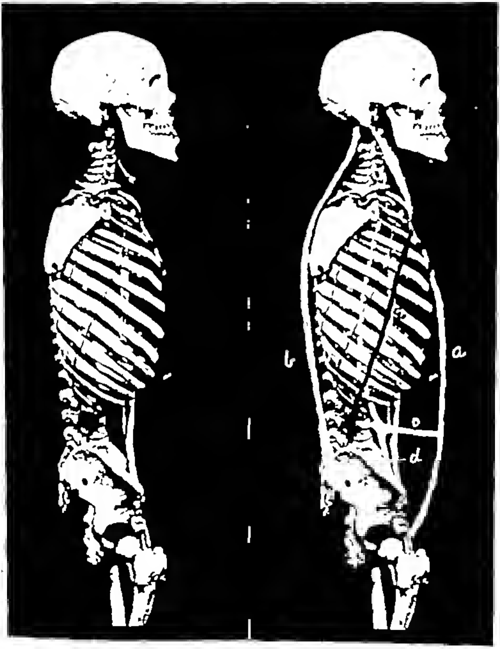


FIG. 5.—Normal physiologic curves. Skeletal support of thorax and shoulder girdle.

FIG. 6.—Schematic representation of general muscular controls of the spine. (After Lovett.) *a* and *d*, flexor group control; *b*, extensor group control; *c*, transverse group; *e*, rotator group

of 50°, in the dorsal region are more vertical and in the coronal plane, and in the lumbar region are nearly vertical and in the sagittal plane, with the exception of the lumbosacral articulations, which are more in the frontal plane, thus permitting greater flexibility in the anteroposterior movements. Thus each vertebra articulates with the one above at three joints, forming with each other a triangle. It is difficult to see how there could normally be much movement between two adjacent vertebrae or even much movement in the entire spinal column, particularly in light of the fact that all three articulations are firmly surrounded by dense ligaments.

The articulation of these segments results in an osseoligamentous column, pyramidal in shape, containing in the canal produced by the foramina of the vertebrae the spinal cord and thus serving as an organ of protection. Its other functions are maintaining the vertical position of the human body, sustaining the superimposed weight and support of the thorax, providing for flexibility and resilience, supporting and protecting the thoracic and abdominal viscera, and being the source of origin for a vast system of complex musculature.

To provide flexibility, resilience, and stability there are in the anteroposterior direction three curves, the cervical (convex anteriorly), the dorsal (convex posteriorly), and the lumbar (convex anteriorly). See Figure 1. These curves are known as the physiologic curves and their relationships to each other are of the greatest importance. The summit of the convexity of the cervical curve is at the level of the fifth cervical vertebra; that of the dorsal curve, at the sixth; and that of the lumbar curve, at the fourth. In the transverse direction there is normally no curve except a slight deviation convexly to the right extending from the middorsal to the midlumbar region and said to be associated with the disposition of the vascular structures.

Support of the thorax is afforded by articulations with the spinal column of the 12 ribs on each side (Fig. 5). From the second to the tenth ribs the head of the rib articulates with both the corresponding vertebra and the one below by a double joint, while the first rib usually articulates only with the body of the first dorsal vertebra, and the last two ribs, with the eleventh and twelfth vertebrae, respectively. Moreover, the first to the tenth ribs have an additional articulation with the corresponding vertebra through their tubercles and the transverse vertebral process. In this manner the thoracic cage is suspended and supported from the vertebral column and its shape is accordingly modified by changes in the relations of the spinal support.

Musculature of the Spine.—Like all other joints or systems of joints, the maintenance of stability, strength, and form is dependent not alone upon articular or immediate periarticular structures, but in great measure upon those extrinsic elements which normally affect the movement of the joint, namely, the muscles; and in the spine these are massive and complex in their normal states and of inestimable

viz., the sternocleidomastoid considered singly, the broad, strong, external oblique muscle of the abdomen extending from the eighth rib downward, forward, and mesially to be inserted into the sheath of the rectus abdominis, Poupart's ligament, and the iliac crest. The internal oblique muscle of the abdomen is similar in arrangement except for obliquity in the opposite direction, arising from the iliac crest and lumbar fascia to be inserted into the ribs, sternum, and rectus sheath.

Transverse.—The transverse group (Fig. 6c) is concerned chiefly with minor movements as far as the spine is concerned but effects concerted action of the upper extremity and thorax with the spine. The pectoralis major and minor, serratus magnus, latissimus dorsi, and trapezius effect movements of the shoulder girdle about the thorax and hence of the spine. Similarly the quadratus lumborum and transverse abdominal muscles effect movement between the thorax and the pelvis.

It is important to consider the continuity of muscular action by these groups from skull to pelvis and even the lower extremities. It will be seen that the movements of the spine are determined and partly limited thereby and that deformity will ensue upon the release of control by any one group, as in paralysis, or upon the abnormal accentuation of the force exerted by any one or more groups, as in muscle spasm incidental to inflammatory process or spastic paralysis. The equilibrium of the spinal mechanism at rest or in movement must be secured largely by the reciprocal action of all muscle elements.

Movements of the Spine.—The voluntary movements of the spine are of course controlled by these longitudinal and transverse muscle pulls within the limits of range permitted by bone and joint elements. The joints permit some movement between all vertebral segments, although they are variable in different portions of the spine, and the tripodal articulation definitely limits the range of movement enjoyed at each intervertebral joint. The intervertebral discs are compressible and on movement adapt themselves in shape, the nucleus pulposus *slipping* forward, backward, or to either side. The articulations of the arch permit gliding movements only, and so the net result is that each intervertebral joint can bend forward, backward, and laterally, and can rotate. In a system of superimposed joints of this sort the maximum mobility of the spine would be the summation of movements permitted by these articulations if the spine were a straight rod, which it is not, and if it were not for other factors of limitation, such as the function of supporting the thoracic cage. Thus the degree of movement and its nature are modified by the relatively fixed nature of the physiologic curves. In the cervical region, flexion, extension, lateral flexion, and rotation are all free in range. In the dorsal region extension is practically absent and flexion is limited, while lateral motion is considerable. In the lumbar region lateral rotary movement is markedly restricted, but flexion is freer and extension is freest.

More important than the exact ranges of movement at different levels

consideration can be given only to the general gross arrangement of those groups which, acting harmoniously, prevent deformity and maintain stability, and the disturbance of any one of which may produce deformity.

The spine must be regarded as the core of a cylinder of muscles which form the trunk, the core being situated posteriorly in the mass. The direction of muscular pull around the core is such that when all muscles are of normal integrity and hence balanced, they act as the physiologic splint of the spine and in every movement of any nature every portion of the splint participates.

Muscle Groups.—There are in general four muscle groups: (1) the extensor group, (2) the flexor group, (3) the rotator group, and (4) the transverse group.

Extensor.—The extensor group (Fig. 6b) is posterior to the spine, extending as a great mass from the pelvis and sacro-iliac ligaments upward on both sides to the base of the skull, with relays of origins and insertions. In addition to directly parallel longitudinal masses, portions at various levels curve laterally to insert into every rib and into the base of the occipital bone. More deeply the interruptions are segmental so that the ribs are connected to the transverse processes of the vertebrae above, and to each other by intercostal muscles, and the transverse processes are joined by little muscle plates. This great mass imbeds the spine deeply except for the spinous processes, all of which can be felt subcutaneously between the two muscle columns.

Flexor.—The flexor group is anterior to the spine and comprises two separate portions, viz., those intimately connected with the spinal column and those of the anterior portion of the trunk. The former (Fig. 6d) consists of an upper portion or cervical group and a lower or lumbofemoral group between which in the dorsal region the continuity is deficient. The upper group arises from the bodies of the fifth and sixth cervical vertebrae and, ascending in relays, is inserted into the bodies and transverse processes of superjacent vertebrae and into the occipital bone. The lower group, the psoas mass, arises from the bodies, intervertebral discs, and transverse processes of the twelfth dorsal to the fourth lumbar vertebrae inclusively and forms a belly which tapers downward over the brim of the pelvis laterally to be inserted near the lesser trochanter of the femur.

The anterior trunk group (Fig. 6a) is likewise interrupted in muscular continuity, but by the unyielding sternum, which subtends the defect. Above, the sternocleidomastoid muscles arise from the mastoid process of the temporal bone and descend to be inserted into the sternum and clavicle. Below, the rectus abdominis extends from the thoracic rim in front to the pelvic brim below. The anterior portion of the intercostal muscles may also be regarded as participating in this group.

Rotator.—The rotator group (Fig. 6e) is composed of muscles of oblique arrangement with reference to head, neck, trunk, and pelvis,

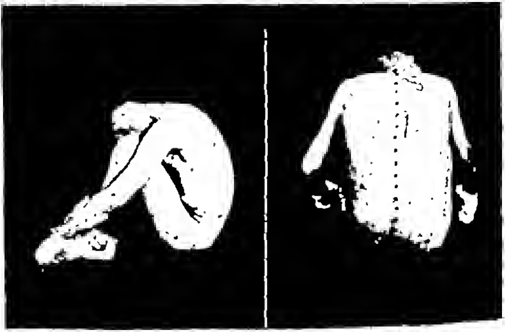
is the result of combinations of these in the spine as a whole, for to the latter must treatment be accorded to affect any deformity. Much of the seeming range of motion is really due to freedom of movement at the occipito-atloid juncture and at the hips, hence the latter must be eliminated by fixing the pelvis to attain an accurate estimate. Lovett[2] and others have emphasized the fact that in a flexible structure possessing fixed anteroposterior curves, lateral bending is necessarily accompanied by rotation; hence there can be no pure lateral movement of the spine without twist, although at different levels the relative proportions of lateral motion to twist in this compound movement vary. Moreover, the ratio is varied by concomitant flexion or extension of the spine as a whole. For details of these elements the reader should be referred to Lovett's monograph, "Lateral Curvature of the Spine."[2]

FIGS. 10 and 11.—Lateral flexion of the normal spine.

In general, forward flexion is a pure movement enabling the conversion of the spine into a curve of approximately one-fourth of a circle (Figs. 7 and 8). The physiologic lumbar curve is obliterated, the dorsal is increased, and the cervical is decreased.

Extension is also pure, i.e., free from rotation, and enjoyed to the degree shown in Figure 9. The movement is chiefly at the lower lumbar segments, although the physiologic dorsal curve is somewhat decreased.

Lateral flexion (and rotation) in the erect position resolves itself into a movement chiefly of the dorsolumbar region (Figs. 10 and 11) and, according to Lovett,[2] is accompanied by rotation of the vertebral bodies toward the concave side of the lateral curve. If, however, lateral flexion is carried out with the whole spine forward-flexed, a greater segment of the spine participates in the lateral curve and the vertebral bodies rotate toward the convex side thereof.



Figs. 7 and 8.—Flexion of the normal spine.

Fig. 9.—Extension of the normal spine.

below, and by retentive apparatus in those cases exhibiting tendency to imbalance.

Structural Curvature.—Structural scoliosis, on the other hand, is marked by the presence of deformity which a normal spine cannot assume, and by definite changes in the form and relation of the bony

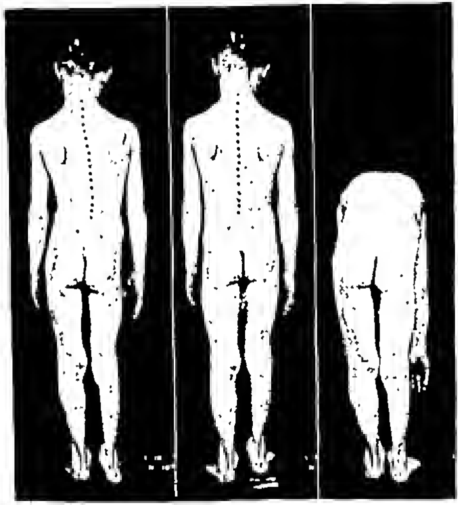


FIG. 12.—Functional scoliosis compensatory to short right lower extremity.
FIG. 13.—Obliteration of deformity of spine by raising right lower extremity.
FIG. 14.—Absence of rotary deformity (structural) in forward flexion

elements of the spine. These bone changes may be primary with reference to the scoliosis, as in congenital malformation of bone, such as "wedge vertebrae" and other developmental anomalies of segments or articulations, or in changes in the shape of these elements due to rickets, neoplasm, granulomatous disease, or trauma.

Lateral flexion and rotation being indissolubly associated and reciprocal, the effort to eliminate one mechanically tends to restrict the other in the normal state, while the converse is true in certain deformities.

To summarize, the anteroposterior normal curves, together with the segmented osseoligamentous structure, assure a flexible mechanism of stability and equilibrium capable of generous mobility as a whole and requiring very little external support to maintain symmetry. The spine is, however, provided with abundant muscular support, which, if balanced, augments these factors and which, if unbalanced, inflicts deformity. Manifestly the plasticity of the structure has much to do with its vulnerability to deformity from external influences. Thus in the mature spine marked degrees of muscular imbalance may be effectively resisted while in the immature spine minor degrees of imbalance may gradually produce extreme deformity. Moreover, intrinsic factors and extrinsic influences other than muscular imbalance may be the elements originating deformity, but once instigated, imbalance ensues and augments deformity.

General Scoliosis (Lateral Curvature of the Spine)

Functional Curvature.—Lateral curvature of the spine may be functional, i.e., unaccompanied by permanent anatomic change in the bones. Such deformity may exist as a normal compensatory reaction to a short lower extremity from any cause (Figs. 12, 13, and 14). There is a singular lack of tendency for such a spine to develop structural deformity. Moreover, in hysterical curvature, although the apparent deformity is obtrusive, there is no structural change. Obviously such forms are not the subject of physical therapeutic ministration. However, another form of lateral curvature primarily apparently functional not uncommonly becomes habitual and may progress gradually into structural changes. This form occurs without apparent cause, usually between the ages of 6 and 12, and is nearly always a deviation to the left. The curve is general, i.e., extends throughout the length of the spine, the maximum deviation being at the level of the ninth or tenth dorsal vertebra. Such a deformity is called a "total" curvature and is usually so gentle that the maximum deviation does not exceed, as a rule, two inches from the median line. Slight degrees of this type may be overlooked. There are no supplementary or compensatory curves and torsion has not occurred, but there is elevation of the left shoulder which is also displaced forward, while the right is displaced backward and the whole trunk is shifted toward the left, as indicated by the plumb line dropped vertically through the fold between the buttocks (Figs. 15, 16, and 17).

It is therefore essential that balance be maintained during the years of growth to avert conversion to the structural type. This is accomplished by general calisthenics for the spinal musculature, described

static factors plus muscular imbalance incidental to the musculature of one side operating to a mechanical disadvantage against that of the other tend not only to perpetuate but to increase the deformity in just the same manner as these influences operate upon an ankle joint. Now when one of these influences is exerted with sufficient persistence in point of intensity and time, particularly upon the growing spine, a curve to the right or left is created and such curve is greater than the normal physiologic movement which the spine could assume in that direction. The convexity of the curve will be opposite the side in which contractural causes operate and usually on the opposite side to the paralysis in unilateral poliomyelitic scoliosis.

As has been pointed out, the spine cannot be bent laterally at any given point beyond a certain limit without introducing the element of rotation or twist, and when such lateral curve is toward the right, the direction of the rotation of the segments is toward the right. In other words, the vertebral bodies rotate toward the convexity of the curve. This torsion occurs, not only between the vertebral segments, but actually in their bodies. When the curvature is in the dorsal spine, the ribs on the convex side are curved backward with the rotating vertebrae, creating the "rotation hump" or gibbus. As the curve develops and the rotation occurs, there is crystallization of the stress of superimposed weight upon the portions of the vertebral bodies on the concave side, and in response to Wolff's law, they become wedge-shaped (the base laterally) and otherwise distorted. Torsion is not confined to the immediate vicinity of the lateral curve but goes on above it, so that there develops a twist of the shoulders in relation to the pelvis.

The ribs on the concave side are carried forward, accentuating the hollow in the back on that side, and the thorax thus becomes deformed. Attempted adaptive and compensatory adjustments resolve the deformity into one that must be regarded as no longer of the spine alone, but of the entire body. The patient in an involuntary effort to compensate for such a disturbance of mechanics shifts weight to the extremity on the side of the convexity and general disalignment of trunk and extremities ensues.

Untreated, structural scoliotic deformity does one of two things: either it becomes spontaneously arrested at a certain point and the patient goes through life without serious disability, or it progresses gradually to a degree that terminates life at a comparatively early age. In the latter, deformation of the thorax distorts and compresses the respiratory and circulatory viscera, impairing the functions of both and resulting in impaired aeration and circulation, lowered resistance, emaciation, and susceptibility to secondary infection. The thorax collapses into the pelvis until the ribs impinge upon the ilium, inflicting similar embarrassment upon the abdominal viscera. Such individuals seldom reach advanced years, being carried off by pneumonia or other terminal disease.

Much more commonly, however, the osseous malformation is secondary to an extrinsic factor, acting to produce deformity gradually. Of these, infantile paralysis is by far the most common, as indicated by the fact that it caused 80 per cent of my cases. Other forms of paralysis, such as meningomyelitis, spastic paralysis, and dystonia muscu-

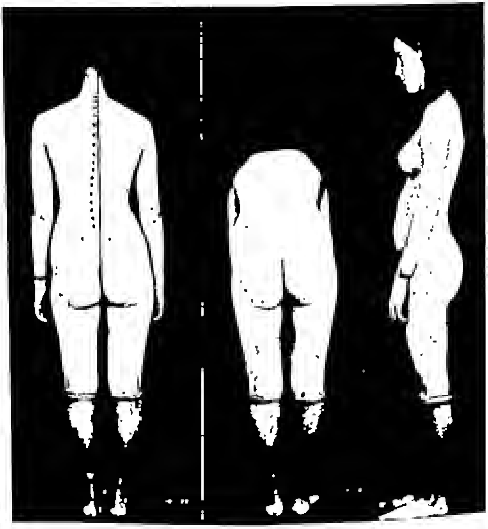


Fig. 15.—Total scoliosis (early functional).

Fig. 16.—Same as Fig. 15, flexed. No rotary fixed deformity.

Fig. 17.—Same as Fig. 15, lateral view. Note general slouching attitude typical of prescoliotic posture

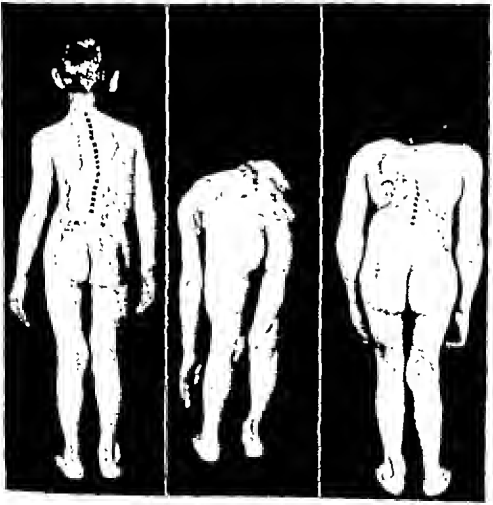
lorum, may create imbalance to the degree of structural change. Contracture of one side incidental to cicatrization of pleurisy or empyemic process or traumatic lesion of chest cavity, wall, or even skin may result in structural scoliosis.

No matter what the origin, once structural change is established,

2. Acquired scoliosis:

   A. Anatomic asymmetry outside the spine
      1. Torticollis
      2. Asymmetry of the pelvis
      3. Unequal length of lower extremities
      4. Ocular asymmetry

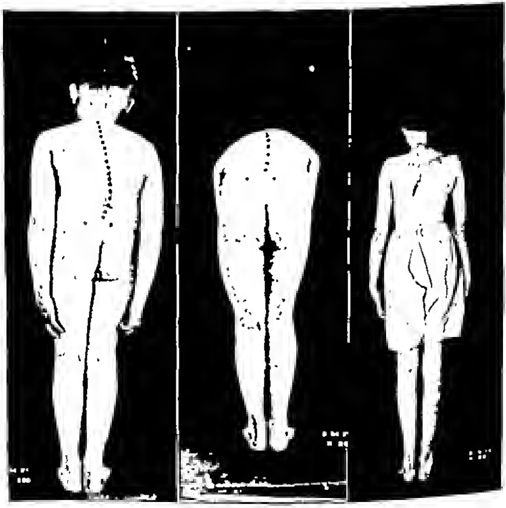
   B. Disease of bones or joints of the spine
      1. Rickets
      2. Tuberculosis of the spine
      3. Arthritis of the spine
      4. Osteomyelitis of the spine
      5. Tumors
      6. Fracture or dislocation



FIGS. 21 and 22.—Scoliosis due to rickets.
FIG. 23.—Scoliosis due to chondrodystrophy (kyphoscoliosis).

Etiology.—Inasmuch as the wisdom of attempting treatment at all and the prospect of any success depend to a considerable degree upon the extent and degree of fixation of the deformity and the causative agency, one considering treatment should recall the many etiologic factors in this deformity. These may be summarized as follows:

1. Congenital scoliosis:
   A. Developmental anomalies of the vertebrae
      1. Wedge-shaped vertebra (one or more)
      2. Absence of one side of vertebra (one or more)
      3. Fusion of two or more vertebrae on one side
   B. Embryologic malformation of the thorax
   C. Deformity *in utero* from pressure



Figs. 18 and 19.—Congenital scoliosis due to wedge-shaped vertebrae.
Fig. 20.—Acquired scoliosis secondary to left torticollis.

It is evident in regarding the list of causes that many will not yield to physical therapeutic measures and that surgical or other orthopedic procedures directed toward the underlying pathology are indicated. Illustrations of scoliosis from different causes are shown in Figures 18 to 27, inclusive. (Figs. 18 and 19 show the congenital. Figs. 20-27 show the acquired.)

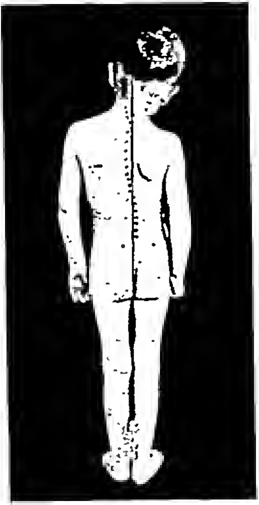


FIG. 27.—Scoliosis due to contracture of right thoracic cavity following old empyema.

Treatment.—PROPHYLACTIC.—Prevention, as in all other deformities, is of the greatest importance. Routine examination of school children will aid in the early recognition of beginning deformity or prescoliotic evidences. Congenital scoliosis can thus be recorded, watched, and controlled. Prescoliotic indications, such as the inclination to assume asymmetrical attitudes in standing or sitting, or "postural slouches," ocular deviations, and rachitic round back, accompa-

7. Osteochondritis
8. Dyschondroplasia and chondrodystrophy

C. Deformity due to disturbance of muscle balance
1. Infantile paralysis
2. Spastic paralysis
3. Dystonia musculorum
4. Inflammatory or traumatic muscle spasm, lumbago, sciatica, sacro-iliac disease, hip joint disease
5. General muscular atony from any cause
6. Muscular dystrophy
7. Encephalitis lethargica

D. Contracture of extrinsic soft structures
1. Unilateral pulmonary disease
2. Thoracic empyema
3. Cicatrization of the skin from burns or other trauma

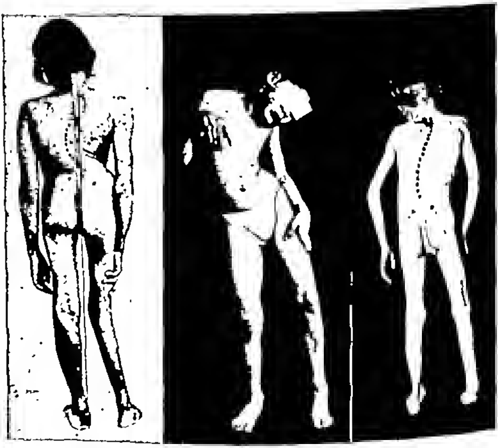
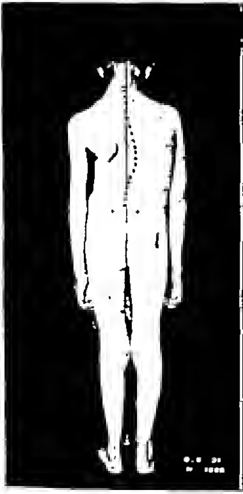


FIG. 24.—Scoliosis due to infantile paralysis which has affected musculature of spine, abdomen, and right lower extremity.

FIG. 25.—Scoliosis due to dystonia musculorum.

FIG. 26.—Scoliosis due to postencephalitic Parkinsonism.

curve I have referred to the associated torsion that occurs and to the tendency for imbalance to occur in the entire body. For instance, when there is a dorsal curve to the right, in order to retain the center of gravity the body weight is shifted more to the right lower extremity than to the left. This is an early effort of the body to compensate mechanically. Later there develops a curve above and below the primary one in a further effort to establish the center of balance. These curves are known as secondary curves and are in a direction opposite to the primary curve. In this automatic adaptation the body may succeed or fail. In those cases that become stationary or nonprogressive, the secondary curves and the primary one have become reciprocally compensated, and although there are three curves in the spine, the net



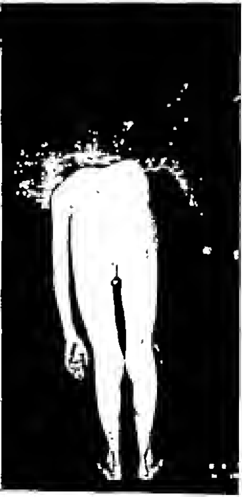


FIG. 18.—Example of compensated scoliosis. Although there are structural change and deformity, the plumb line falls through center of skull and internatal fold and weight is borne equally on lower extremities, i.e., there is no list.

FIG. 19.—Same as Fig. 18, flexed, disclosing torsion deformity.

nied by other evidences of rickets, can be met in advance of real deformity, and by supervision, exercises, and sometimes apparatus, can be controlled during the growing period. Scoliosis can thus be averted.

Of particular importance is a careful study of the spines of children who have had infantile paralysis. Extreme degrees of paralysis may result in little deformity owing either to retention of balance despite loss of power, or to maturity of osseoligamentous structure. On the other hand, seemingly minor degrees of unilateral spinal or abdominal paralysis may result in extreme degrees of deformity and often following a latent period of years. Moreover, many children have mild attacks of poliomyelitis without its having been recognized, but months or years later the scoliotic deformity is observed. Once launched upon the tendency, progression of the deformity is likely to go on apace, and often in spite of intensive opposition in the form of treatment.

Indications and Contraindications.—The principles of treatment in the paralytic type are applicable to all forms in which underlying pathologic causes, such as tuberculous spine, arthritis, etc., do not contraindicate movement, and hence movement is selected as the basis for outlining the routine.

The question should be asked first, "Can anything be expected of treatment?" The answer is to be sought in the degree of fixation of the deformity and in the determination of whether it is definitive and stationary. In the inveterate contracture in the adult there is no prospect of correcting the deformity. In the stationary scoliosis which has arrived at a state of compensation and is not progressing in either adult or child, it had best be let alone as far as efforts to reduce deformity are concerned.

Purpose of Treatment.—The second question to be asked is, "What are we trying to do?" If the answer to the latter is the attempt to unbend and untwist a structural lateral curve and to secure the normal anatomic relation of distorted vertebrae, the optimism exceeds that of anyone who has had experience in the subject. The multiplicity of methods and machines directed to this end testifies to the improbability of such accomplishment.

Arrest of Deformity.—Attention has been called to the fact that structural scoliosis untreated either progresses to a hopeless degree or assumes a definitive state. The ideal of treatment in our present understanding of the subject is to secure the definitive arrested state with the maximum of correction by the application of those measures which convert the progressing deformity into the status of the one that has become spontaneously arrested. This leads to the question, "What occurs spontaneously to arrest deformity in this type?" It is generally accepted at present that this is accomplished by the development of compensatory balance. During the development of a primary scoliotic

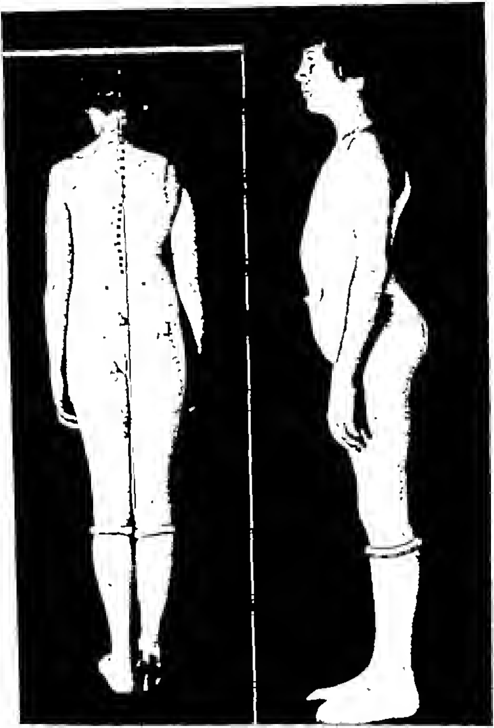


Fig. 30.—Prescoliotic attitude. Lateral curve without structural change. Potentially inclined to become progressive and develop structural change.

Fig. 31.—Lateral view of Fig. 30, indicating tendency to slouch.

result is realignment of the whole so that imbalance has been corrected. In such a case the plumb line will fall through the median line of the cervical vertebrae and through the internatal fold, although the spinous processes will deviate from the line in three areas (Figs. 28 and 29). Now to disturb this mechanism by attempted correction of deformity is to court the danger of breaking the compensation and making the patient worse. Such a spine has already attained the nearest ideal toward which treatment strives, namely, the establishment of compensation. Every scoliotic spine makes the effort to do this automatically, but many fail. Treatment is directed toward helping in that direction.

To this subject most salutary contribution has been made by Steindler,[3] and his conceptions are utilized as the basis of the treatment given herein.

Rehabilitation of Muscles.—In the potential scoliotic patient before structural change has occurred (Figs. 15, 16, 17, 30, and 31), viz., the type of child that assumes asymmetrical attitudes in walking, standing, or sitting, and in the patient whose general musculature has been subjected to deterioration by prolonged illness or recumbency for any reason, the object of treatment is the rehabilitation of the normal splints of the spine—the muscles. Supervised exercises designed to bring into play all the intrinsic and extrinsic musculature effecting spinal integrity are instituted. It is to be assumed that general physical examination has determined whether such a régime is compatible as indicated by the cardiovascular, respiratory, and general conditions. Exercises must be graded carefully, according to the requirements and the capacity of the child. In no instance should either child or muscle be subjected to exercise to the degree of fatigue or weariness. Thus it may be advisable to subject each muscle group to no more than one or two contractions in the beginning, until each can be accomplished with ease and grace. It is important that the therapist be cognizant of the fact that no amount of passive ministration to a muscle in the form of massage can be substituted for voluntary contraction in restoring tone and strength; and passive ministration in these cases should be limited merely to the touch to indicate to the patient the direction of voluntary effort. However, when the latter is insufficient to accomplish a given movement, it should be performed with the passive aid of the therapist until the therapist's assistance is no longer needed. The method of conducting exercises with passive aid is described below under *Exercises B.*

The exercises designed to strengthen all spinal musculature, indicated below under Exercises A, are properly used as supplementary to other more specifically directed treatment in cases of established scoliosis.

Such exercises may be given in classes, but only after each member understands the procedure and has developed a fair degree of muscle capacity through preliminary individual work.

Structural Scoliosis of Paralytic Origin

Diagnosis.—It is assumed that a structural curve has developed. The first procedure is the securing of proper records. These include, in addition to the general physical and orthopedic examination, photographic and radiographic records made under standard technic. Posing for the photograph is ideally done under the direction of either surgeon or physical therapist. The spinous processes are marked with black court-plaster and a plumb line of black is dropped vertically through the internatal fold to determine the median line. The patient stands in natural relaxation with heels parallel to the lens of the camera. Light, distance, and exposure must be invariable if photographic records are to be of value for comparison. This view discloses the location and degree of deviation of spinous processes from the median

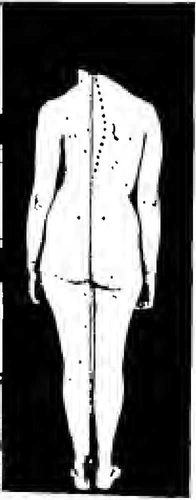


Fig. 34.—Scoliosis lumbodorsal, structural, left, infantile paralytic, severe.

Fig. 35.—Scoliosis cervicodorsal, structural, right, moderately severe.

In the patient whose muscular structure cannot maintain symmetry and balance, the treatment should be supplemented by a light back brace and an abdominal support or a corset (Figs. 32 and 33). In the event that the examination and the experience of the therapist disclose that the musculature of one or more groups is weaker comparatively than that of others, particular attention should be given to that group, and in such cases external support is particularly indicated.

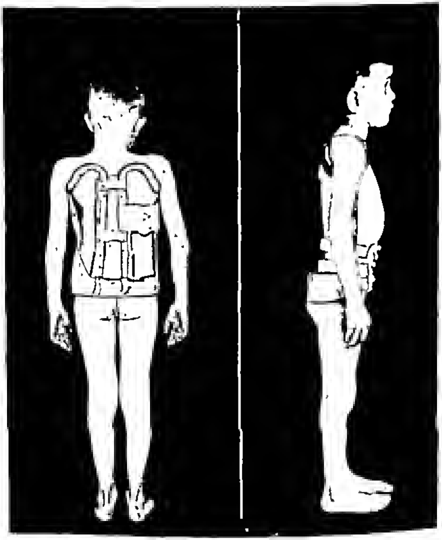


FIG. 32.—Type of brace for support of prescoliotic patient between exercises. To be worn most of the time when up and about until musculature appears competent. The brace must be light, hence it should be made of aluminum and adjustable posteriorly and laterally.

FIG. 33.—Another type: light but effective brace.

line and the shift of the trunk to one side or the other. The second exposure, which is made from behind with the spine flexed, records the degree of torsion as indicated by the gibbus which is on the convex side of the curve in structural cases and in the same area as the primary curve. *If it is on the opposite side, the case must be regarded* as functional scoliosis (Fig. 14).

The degree of rotation of the trunk is estimated by looking downward from above, behind the patient, and determining the relation of the scapulae or shoulder girdle to the pelvis.

*Radiographic study is made of the whole length of the spine antero*posteriorly, not only to determine the degree of primary and secondary curves, but to note the extent of deformity in the vertebrae and ribs.

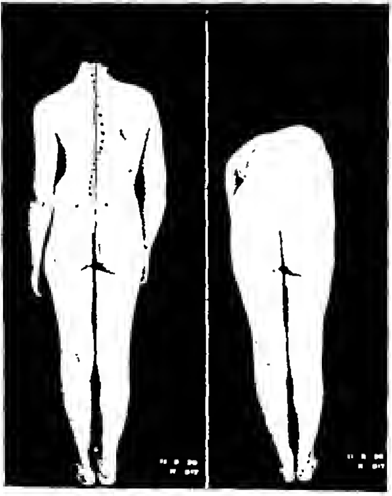


Fig. 39.—Compensated right dorsal structural scoliosis. No list; axial balance maintained for years.

Fig. 40.—Compensated right structural dorsal scoliosis, exhibiting degree of rotary deformity.

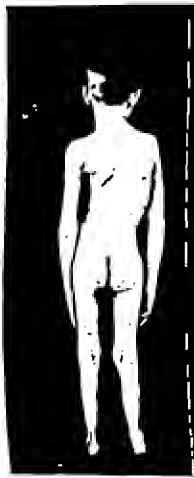


FIG. 16.—Determining flexibility. Right structural paralytic dorsal scoliosis, standing naturally.

FIG. 17.—Determining flexibility. Application of head traction apparatus.

FIG. 18.—Determining flexibility. Traction applied. Note extreme flexibility as indicated by great decrease of deformity and lengthening of the trunk.

ing it. Determination at this point must be made as to whether the case at hand is in a state of compensation. If so, the future treatment should be directed toward keeping it so; if not, it should be designed to make it so.

By compensation is meant the state in which the primary and secondary curves and torsions counteract each other to the degree that the central axial line remains vertical and central, thus maintaining balance (Figs. 39 and 40).

By decompensation is meant the absence or insufficiency of compensatory secondary curves, permitting shifting of the whole superimposed trunk to one side with the pelvic center in one axis and the cranial center in another, creating leverage which adds the effect of

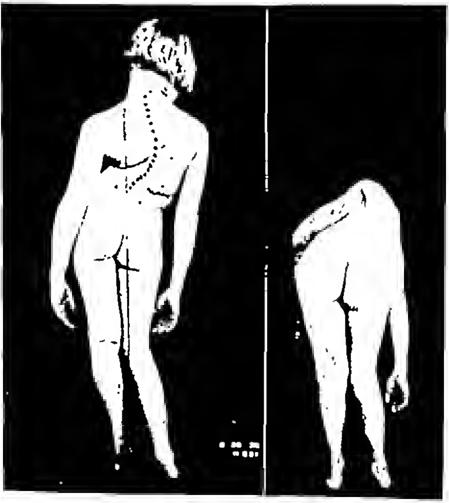


FIG. 43.—Decompensation (advanced) in right structural dorsal scoliosis. Note extreme list, complete loss of center of gravity, and absence of compensatory curves.

FIG. 44.—Same as Fig. 43.

Observation should also be made in the prone position, for therein the functional curve disappears and the structural curve is modified by relief from superimposed weight.

Descriptive record is thus made as the diagnosis. Scoliosis is described as to the location of the primary curve, the degree thereof (whether it is structural or functional), and its etiology. For instance: Scoliosis: lumbodorsal, structural, left, infantile paralytic, severe (Fig. 34); or scoliosis: cervicodorsal, structural, right, infantile paralytic, moderately severe (Fig. 35).

The flexibility should be recorded because of its important relation to treatment. It may be visualized by suspension of the trunk by the head (Figs. 37 and 38). The more rigid the spinal curve, the more resistant it is to continued increase in itself and to efforts at decreas-

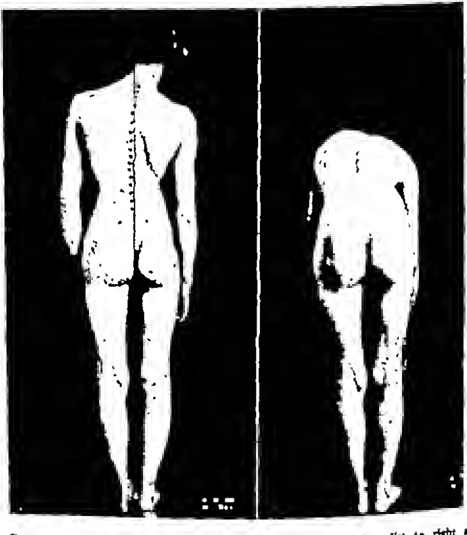


FIG. 41.—Decompensation (early) in left dorsal scoliosis. Note list to right and absence of compensatory curves

FIG. · -Same, revealing rotation.

ing it. Determination at this point must be made as to whether the case at hand is in a state of compensation. If so, the future treatment should be directed toward keeping it so; if not, it should be designed to make it so.

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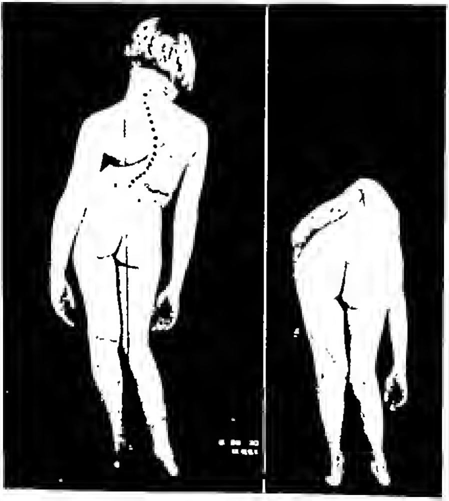

FIG. 43.—Decompensation (advanced) in right structural dorsal scoliosis. Note extreme list, complete loss of center of gravity, and absence of compensatory curves.

FIG. 44.—Same as Fig. 43.

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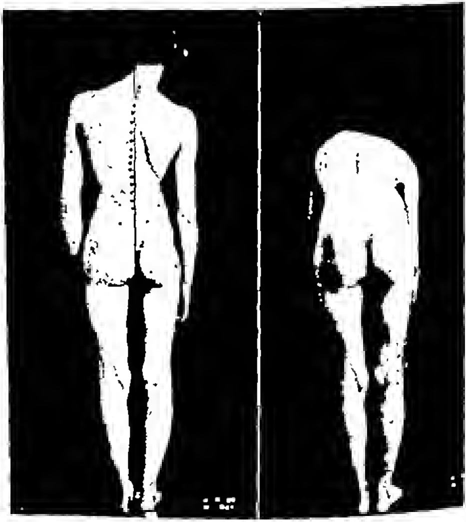


FIG. 41.—Decompensation (early) in left dorsal scoliosis. Note list to right and absence of compensatory curves.

FIG. 42.—Same, revealing rotation.

At any time, particularly during the growing period, the compensated scoliosis may lose its balance and become decompensated, and then the primary curve progresses and the secondary curves become relatively decreased. This "breaking" of compensation occurs most commonly at the lumbodorsal juncture. It is possible in some instances to regain compensation by means of a brace and exercises and passive efforts at reversing the direction of the leverage of superimposed weight. These are outlined below under shifting exercises. This régime

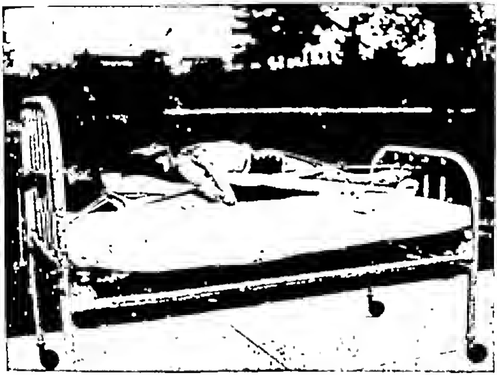


FIG. 47.—Treatment of decompensated scoliosis. Head and pelvic traction upon curved Bradford frame. Breathing exercises may be administered during this period.

must be continued for an indefinite period, preferably until maturity of bony structure.

Treatment.—In the early case of decompensated scoliosis in which balance cannot be reëstablished. and in the confirmed state of decompensation, treatment must be directed toward the artificial creation of compensatory curves and the maintenance thereof by apparatus, and toward the rehabilitation of the musculature in its new relation to enable it to maintain the curves without apparatus. Failing in the latter, one has the choice between continued apparatus and operative ankylosis of part or all of the primary curve and part of the secondary curve.

gravity to the contractural element of the primary curve, and causing it to collapse further (Figs. 41-46).

In the compensated type the record must be kept for comparison at intervals to detect evidences of decompensation, and treatment consists in exercises for the prescoliotic patient as outlined above and in special corrective exercises indicated below (Exercises C).

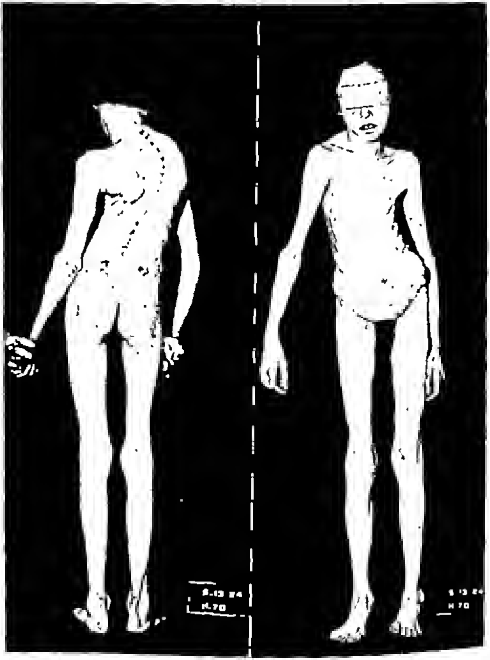


FIG. 45.—Same as Fig. 44.

FIG. 46.—Confirmed decompensation. Fixed spine in extreme disalignment deformity of thorax and impairment of general health.

the gymnasium for the exercises (Fig. 47). The latter, both active and passive, must be directed toward mobilizing the lumbar and cervicodorsal portions of the spine as described in Exercises C and D.

The establishment of compensatory curves or the beginning thereof requires several weeks. When the curves have been attained to the degree that the mobilized spine may be passively placed in an attitude which is the reverse of its former inclination, viz., with the summation of the upper and lower curves equal to the primary one and with the pelvis rotated to the side opposite its former relation to the shoulders, a plaster jacket and spica are applied to retain this correction, the jacket being provided with windows for pads to accentuate it (Figs. 48 and 49).

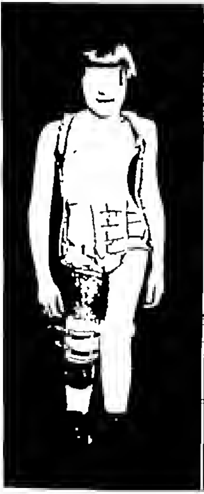


FIG. 50.—Same as Fig. 48, anterior view.

FIG. 51.—Brace used for support after removal of plaster dressing.

Artificial Creation of Compensatory Curves.—Older forms of treatment consisted of energetic, forcible redressment, stretching, and apparatus designed forcibly to unbend the primary curve, a procedure now considered inadvisable because it removes one quality of service in preventing further deformity, viz., the rigidity of the primary curve. In less forcible application of such measures, although clinically and radiographically there appears to be a decrease in the primary curve, the important result is the formation of new curves above and below. To enhance the latter, the unfixed portions of the spine are limbered by gymnastics, mobilizing exercises, and head and pelvic traction in recumbency. The patient is maintained on a Bradford frame, with traction upon the head and the pelvis, and is removed twice daily to

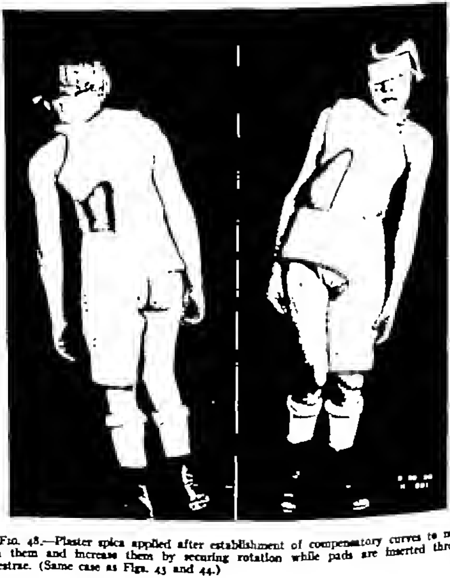
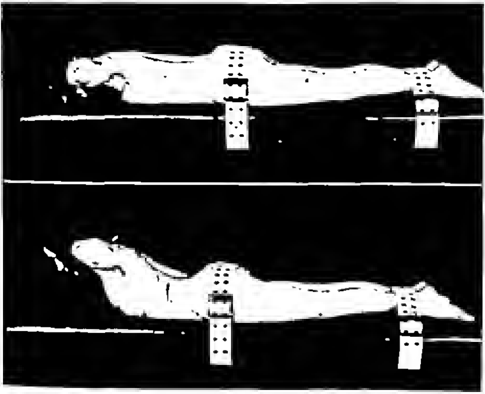


Fig. 48.—Plaster spica applied after establishment of compensatory curves to maintain them and increase them by securing rotation while pads are inserted through fenestrae. (Same case as Figs. 43 and 44.)

Fig. 49.—Same. Anterior view

for the spine; (B) passively aided muscle training; (C) asymmetric muscle training in particular deformity; (D) passive manipulative procedure to mobilize the spine and create compensatory curves.

SYMMETRICAL MUSCLE TRAINING.—The object to be attained is equal development of the spinal musculature—viz., the extensor, flexor, lateral flexor, and rotator groups. This is best done with the patient recumbent, when the factors of weight-bearing in the upright



FIGS. 51 and 53.—Extensor muscle training.

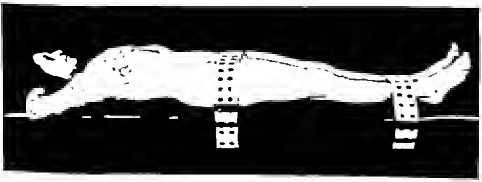


FIG. 54.—Flexor group training.

The plaster is applied with head traction with the patient in the standing positioo. The arm on the side opposite the curve is strongly elevated. The lower extremity on the same side, i.e., opposite the convexity, is abducted. This position accentuates the secondary curves. The trunk is steadied by pressure over the anterior and posterior prominences of the deformed thorax, and while the patient assumes the attitude of the shift, the plaster is applied from neck to knee on the abducted side, rotary relation of pelvis and shoulders also being secured.

A fenestra over the gibbus permits insertion of felt pads from time to time (Fig. 50). The child may be up and about and the plasters may be changed at intervals for a period of from three to six months.

Upon the removal of the plaster a brace is applied to retain the positions secured by the plaster (Fig. 51) and physical therapy is resumed, consisting of shifting and the general calisthenics outlined. Photographic and radiographic records are again made for comparison months and years hence. The problem now is to retain what has been accomplished. The general exercises and brace are to be continued for two years at least. Swimming and the ordinary activities should be encouraged withio reasooable limits.

In addition to the general exercises outlined, breathing exercises, both naturally and by expiration against resistance with Wolff bottles, are valuable in cases in which the thoracic area has been encroached upon by deformity.

Recurrence of decompensation justifies repetition of the whole procedure and fusion in selected cases.

Rehabilitation of Musculature: Physical Therapy.—The part of the physical therapist in scoliosis may thus be summarized:

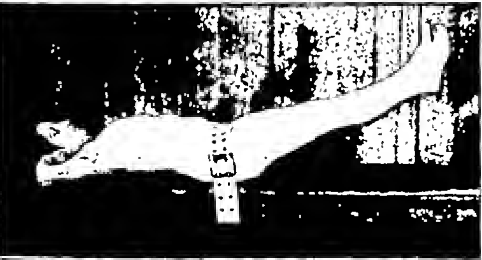
(1) Potential scoliosis
  a. General muscle training: posture work
(2) Compensated scoliosis
  a. General muscle training
  b. Shifting exercises
(3) Decompensated scoliosis
  a. Mobilization exercises
    1. Creeping
    2. Passive stretchings and torsions
  b. Retentive exercises
    1. General muscle training
    2. Swimming
    3. Breathing exercises
    4. Shifting exercises

For the purpose of description the technic (consisting of exercises) will be divided as follows: (A) symmetrical general muscle training

54-57; the lateral flexor groups, as in Figures 58-60; and the lateral and rotator groups, as in Figures 61 and 62.

PASSIVELY AIDED MUSCLE TRAINING.—When the patient cannot voluntarily accomplish one or more of the group movements, the voluntary effort is augmented by the therapist's passive aid. It may be advisable to commence with a limited range of the desired movement and gradually increase the range. The application of passive aid to muscle training is illustrated in Figures 63 to 73, inclusive.

ASYMMETRICAL MUSCLE TRAINING AND MOVEMENTS.—This group of exercises is used in the compensated scoliosis to assure its maintenance; in the early decompensation, to attempt to regain compensation; and in the decompensated case, while undergoing traction in bed, to create compensatory curves. The technic varies with the deformity at



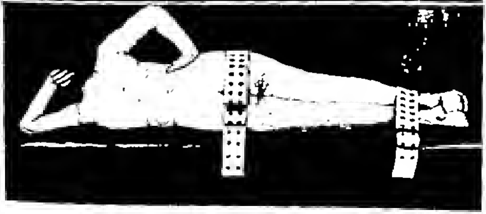
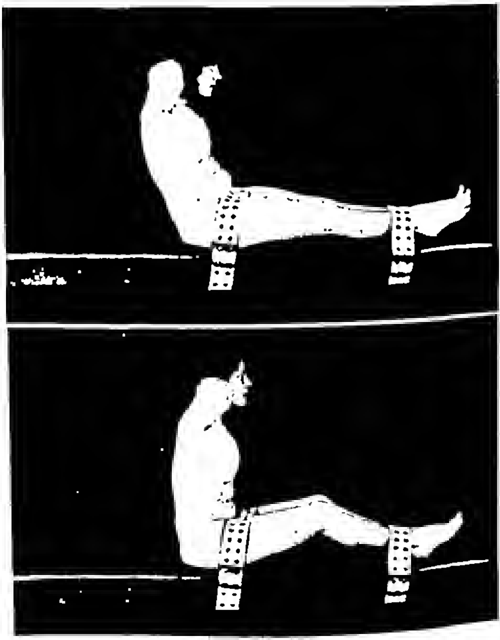


FIG. 57.—Flexor group training.
FIG. 58.—Lateral flexor training.

position are removed. By test it must be determined whether the patient is capable of carrying out the movements. If one or more movements are especially weak, it is well to neglect the others and to concentrate on this one, with passive aid as described under "B."

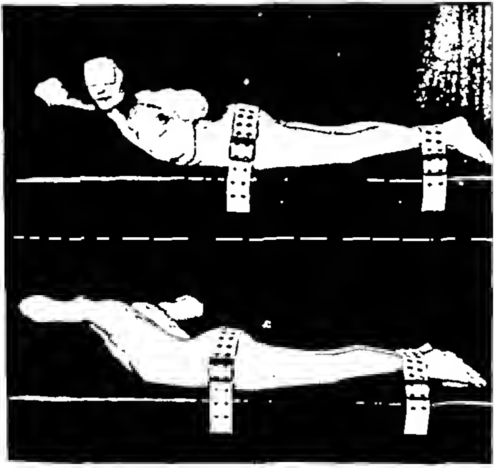
Shifting and insecurity of the pelvis must be eliminated by strapping. Movements must not be hurried or jerky, but slow and complete in range. The illustrations are self-explanatory. The extensor group is trained as in Figures 52 and 53; the flexor groups, as in Figures



FIGS. 55 and 56—Flexor group training.

the balance. The exercise is carried out several times within the limits of fatigue.

These are supplemented by the *creeping exercises* described by Klapp [1] (Figs. 78-72). Locomotion by means of hands and knees is a general exerciser of spinal musculature if done symmetrically, and when carried out asymmetrically, it both mobilizes and exerts a corrective influence. The movements are carried out with a voluntary stretching of the concavity of the scoliosis at each upward and forward



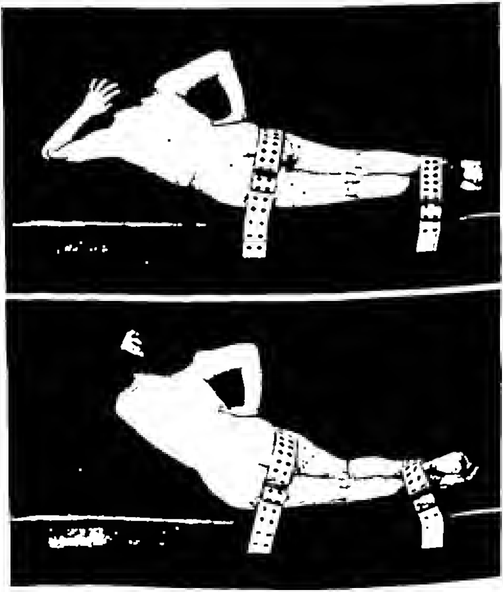
FIGS. 61 and 62.—Lateral and rotator training.

thrust of the left upper extremity (Fig. 79), and the movement is repeated with progression of crawling.

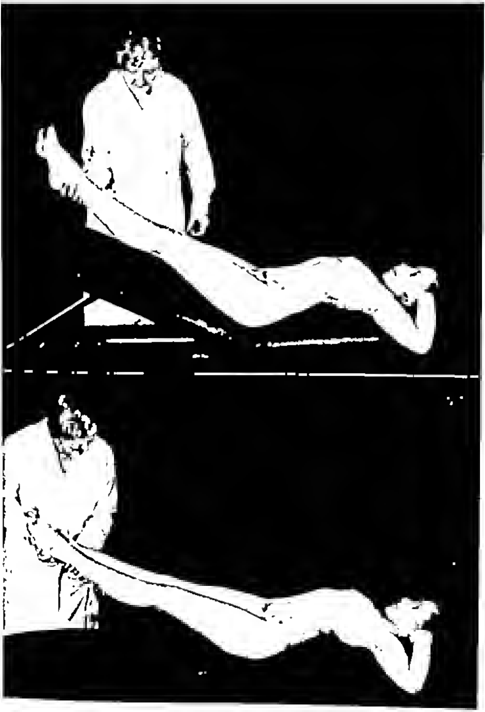
In addition, *asymmetric lateral flexion* is performed, accompanied by voluntary passive stretching by the patient (Fig. 83). In this the patient voluntarily contracts the muscles on the convex side of the curve while utilizing the upper extremities as levers for passive stretching of the concave side. This is done rhythmically and slowly.

hand. As an example, a typical decompensated right structural dorsal scoliosis of paralytic origin is shown in Figures 74 and 75. The patient was retained in recumbent head and pelvic traction while Exercises B were carried out in addition to efforts to mobilize the compensatory curves by means of the shifting exercises.

For the *shifting exercises* the patient stands erect with the hands resting firmly upon the pelvis and, by direct downward push with the upper extremities, applies upward push upon the trunk to the maximum degree of correction of the curve (Fig. 76). While this position is held, the trunk is shifted to the extreme degree to the side opposite the curve (Fig. 77). This tends to accentuate campensatory curves and to realign

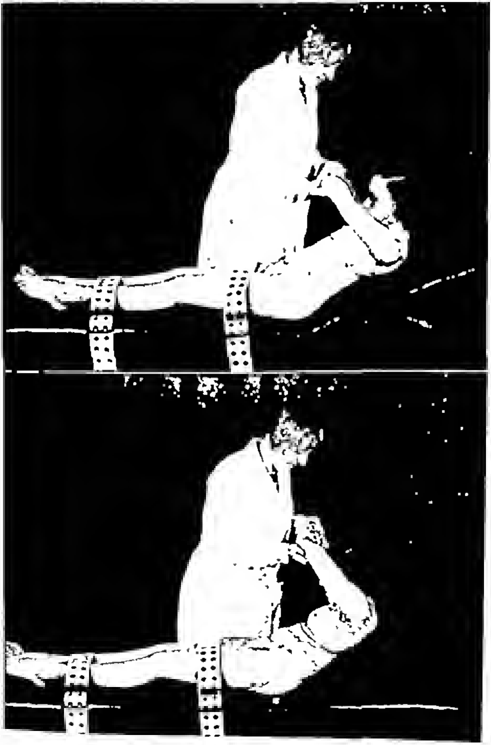


FIGS. 59 and 60—Lateral flexor training.

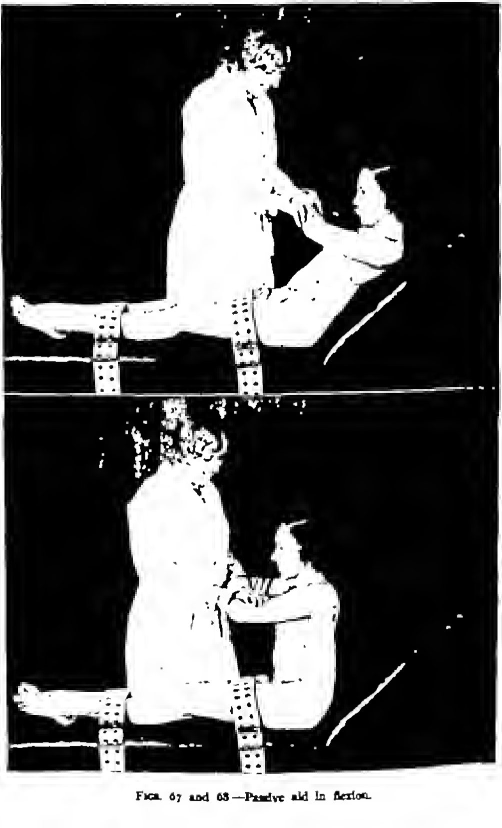


Figs 65 and 66—Passive aid to flexion, increased range.

Figs. 63 and 64.—Passive aid to flexion, limited range.



FIGS. 69 and 70.—Passive aid in flexion.



FIGS. 67 and 68.—Passive aid in flexion.

knee is flexed rhythmically, adding weight to the corrective influence of the traction. To these exercises may be added the asymmetric use of any of the general muscle-training exercises outlined in A and B.

Passive manipulative procedures.—For the sake of simplicity the numerous mechanical devices for exerting forcible traction and passive movement will not be enumerated. They are all based upon the effort to secure hold upon the trunk by fixation of the pelvis and by utilizing the upper extremities and thorax to apply pull, rotation, and corrective flexion. It is doubtful if complicated apparatus will retain a

Fig 73.—Passive aid in rotation.

place in this field, and it certainly never will assume the place of the well-trained, devoted physical therapist who intelligently applies the simpler procedures above outlined. After all, the present knowledge of the subject eliminates the urge forcibly to unbend and untwist a scoliotic curve, and it is apparent that the desideratum, i.e., the compensation, can be secured without it and that nothing else can be secured with it. Moreover, rapid forcible correction is utterly out of the question, therefore all that can be expected of apparatus is to spare the physical labor of the physical therapist. Every movement tending to act in a direction opposite to the tendency of the deformity, whether active

A similar influence is exerted by the *standing suspension and abduction exercises* (Fig. 84). The left hand grasps the bar in a manner to extend the scoliotic curve by traction while the right lower extremity, aided by the right hand which depresses the right shoulder, is gradually and rhythmically abducted. Thus the right shoulder and the lower extremity are approximated, and while they are in this position the left

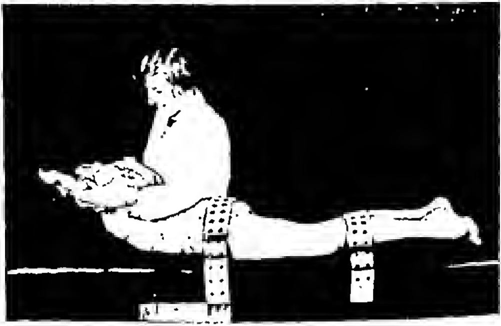


Fig. 71.—Passive aid in extension.

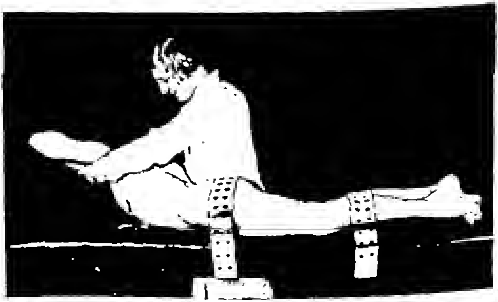


Fig. 72.—Passive aid in lateral flexion and extension.

consists merely of a hinged table in which the point of bending may be used as a fulcrum at the summit of the primary curve with the patient keeping himself in traction by holding on with his hands.

The model used for this series of exercises (B, C, D) was subjected to the routine of decompensated scoliosis, viz., recumbent traction; mobilization; corrective exercises B, C, and D; the shift plaster spica (Figs. 91 and 92); a brace; and indefinite continuation of the asymmetric muscle-training and shift exercises. Compensation has been attained to the degree shown in Figures 93 and 94, and will gradually increase. The régime must be continued until the spinal structures mature.

It is justifiable when in doubt as to the necessity of apparatus or of head and pelvic traction to attempt the use of physical therapy alone and to observe the course, for there are severely decompensated

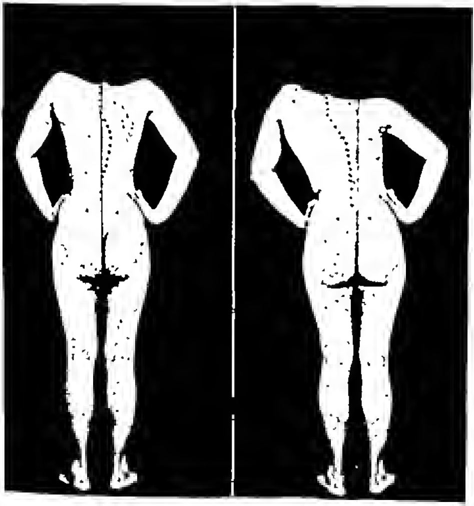


FIG. 76.—Shifting exercise. Movement No. 1.
FIG. 77.—Shifting exercise. Movement No. 2.

or passive, is capable of oft-repeated exertion by the patient and the therapist if there is mutual understanding of the aim.

The simplest and most effective measures of passive ministration are head and pelvic traction in recumbency, the shift plaster described, and suspension of the patient by the arms and head. Voluntary stretching while suspended on the rings is illustrated in Figures 85 and 86. The patient hangs on the rings and by rhythmic movements in the position shown in Figure 86, stretches the concave side of the curve and contracts the opposite. This may be supplemented by passive application of gravitational traction in the Sayre device (Figs. 87 and 88). These same principles are applicable by means of apparatus counterbalanced by weights, in which the efforts of the operator are exerted with less work, such as the device in Figures 89 and 90, which

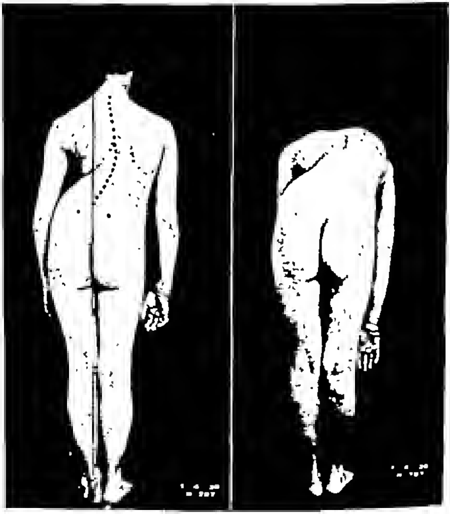
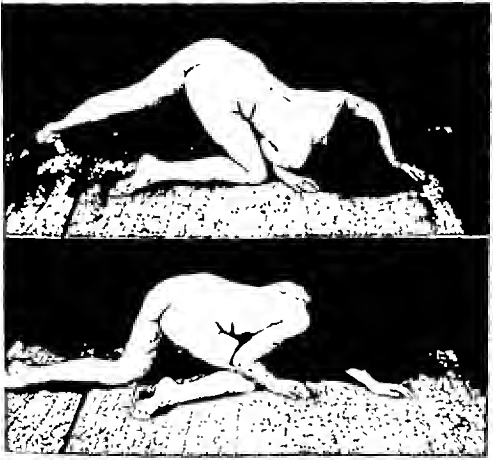


FIG. 74.—Right structural dorsal scoliosis decompensated model for Exercises C.
FIG. 75.—Same. In flexion.

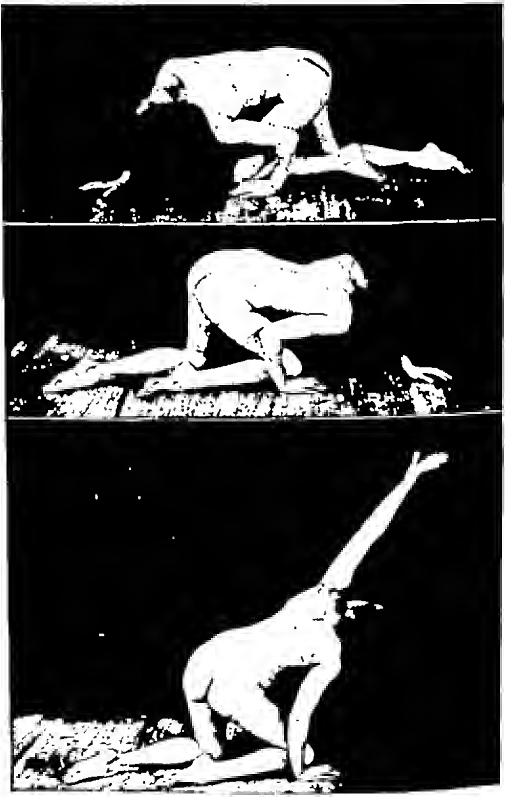
curves that respond readily without the tedium of the longer routine. Such an instance is well illustrated in Figures 95 and 96, which depict severe imbalance and list and no effort at compensation. The patient possesses excellent musculature throughout; the capacity to shift is shown in Figure 97, and with no other treatment than physical therapy she has attained correction of balance as indicated in Figures 98 and 99.



Figs. 81 and 82.—Creeping exercises.

The patient must be impressed with the necessity of indefinite continuation of observation and physical therapeutic work at home.

The mere presence of deformity must not lead the surgeon or therapist into treatment of a stationary curve. Figures 100 and 101 exhibit extreme deformity which, without treatment other than a brace, maintains equilibrium and compensation and hence should not be interfered with. The patient was not seen for two years, when he returned improved (Figs. 102 and 103).



Figs. 78, 79, and 80.—Creeping exercises.

structure directly by operation. The maximum correction of the primary curve and the creation of the secondary curves having been attained through the measures hitherto described, the bony structures of the spine are exposed and, by operative measures, converted into a rigid segment, either by a bone graft or by plastic bone operation upon the vertebrae. Details of the procedure may be found in standard works or orthopedic surgery. An instance is illustrated in Figures 109-

FIG. 84.—Suspension and abduction exercise.

112 wherein, in the presence of extreme tendency to decompensation, the spine was fused surgically from the sixth dorsal to the second lumbar vertebra with resulting maintenance of stability and alignment. In this field, however, disappointments and relapses in loss of equilibrium after operative treatment are not uncommon.

In Figures 38 to 88 inclusive the seemingly remarkable degree of

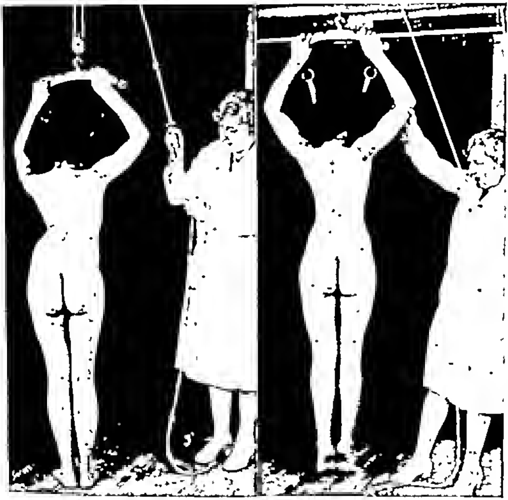
Furthermore, enthusiasm for physical therapeutic measures should not lead the therapist to ignore the effectiveness of measures of external support. Indicative of this feature is a case of spastic dystonic scoliosis of severe degree (Fig. 104) made worse by any active or passive measures of physical therapy. When held in plaster for months (Figs 105 and 106), and later in a brace, the scoliosis subsided with decrease in the intensity of muscle hypertonicity to the degree shown in

FIG. 83.—Asymmetric lateral flexion aided by voluntary passive stretching.

Figures 107 and 108. If the patient had not been supported artificially, this curve would have become irretrievably fixed in decompensation.

Occasionally experience may convince one of the advisability of making the spine stiff by "splinting from within." In other words, the extrinsic elements upon which reliance must be placed to maintain compensation are undependable. This having been determined (and it is a delicate determination), it becomes necessary to attack the skeletal

The impressions given herewith are based upon the writer's experience with approximately 175 cases of scoliosis in the last ten years, but they have originated largely in the substantial contributions to the literature on this subject by R. W. Lovett,[2] Arthur Steindler,[3] W. Schulthess,[4] and others from whose writings I have borrowed.



Figs. 87 and 88.—Passive vertical traction.

Dorsum Rotundum (Round Back)

The deformity of the spine incidental to loss of stability from any cause may be confined to anteroposterior deviations. In other words, there is no lateral curve or torsion.

Any factor causing loss of tonicity of the general musculature or softening of the osseous or cartilaginous structures of the spine tends to result in longitudinal collapse which is followed by pathologic

passive correction of scoliosis by means of vertical traction has been disclosed, and one is impressed by the fact that if such a degree of corrective influence could be perpetually exerted, the outlook in general would be better. This impression has been corroborated in my experience with those who, because of paralysis of the lower extremities, have been obliged to use crutches to such a degree that one might be tempted to designate crutches as one of the most effective means of treating this complex and intractable deformity (Figs. 113, 114, and 115).

Conclusion.—In conclusion, one must not at best regard the prospect in scoliosis with optimism. It is a field which requires all the ingenuity of the surgeon and the physical therapist and is fraught with many disappointments. In it more than in any other field, perhaps, are teamwork, patience, and pertinacity essential.

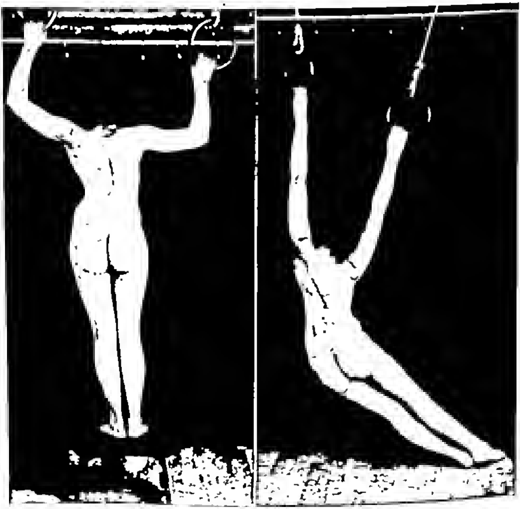


Fig. 85.—Passive voluntary stretching on rings.
Fig. 86.—Passive voluntary stretching suspended by the rings.

increase in the physiologic curves. Depending upon the nature of the underlying pathology, the length of time inflicted, and the treatment accorded, the exaggerated curves become more or less fixed. This deformity varies in degree from mild postural relaxation which is readily passively corrected to the great rigid round back of chronic arthritis. In the aged the thinning of the intervertebral discs creates the general forward-bent spine.

Since the treatment of postural deformities is found elsewhere, I confine the present discussion to round back in children, due to changes in the osseocartilaginous structures. Such changes are in the nature of malacic phenomena secondary to either general or local factors. Moreover, the changes may be general throughout the spine or limited to certain areas thereof.

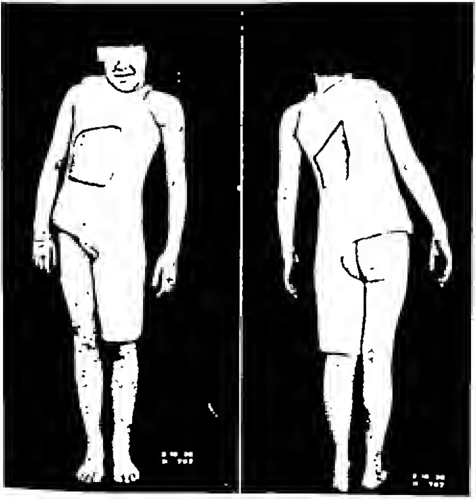
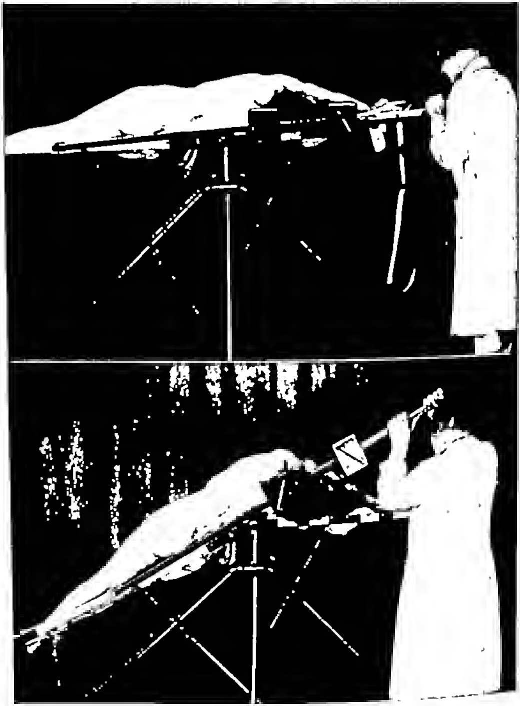


FIG. 91.—Model after application of shift plaster spica.

FIG. 92.—Posterior view of same.



FIGS. 89 and 90.—Traction and passive movement by means of counterbalanced hinged table.

2. Limited portion of the spine
   a. Localized epiphysitis
   b. Localized arthritis
   c. Localized trauma (fracture)

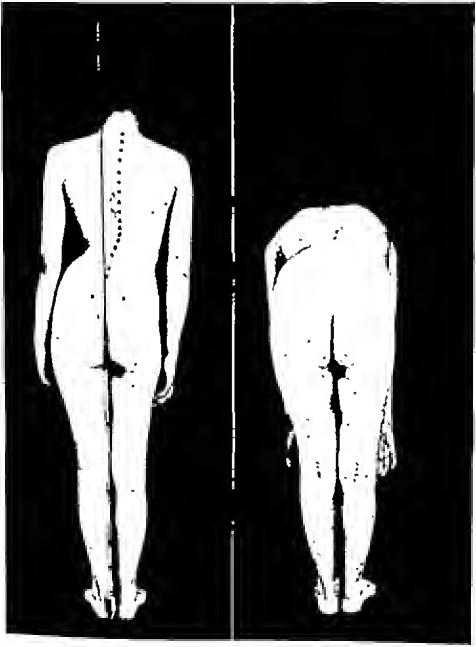


FIG. 95.—Decompensation, lumbodorsal right structural scoliosis.
FIG. 96.—Same as Fig. 95, flexed.

Etiology.—The etiology of fixed round back may be summarized as follows:

1. Malformation of vertebrae or cartilages due to:
   a. General skeletal disease
      1. Rickets
      2. Chondrodystrophy
      3. *Osteomalacia*
   b. Skeletal disease affecting the spine alone
      1. The entire spine
         a. Osteochondritis
         b. Arthritis
         c. Absorption of cartilage in the aged

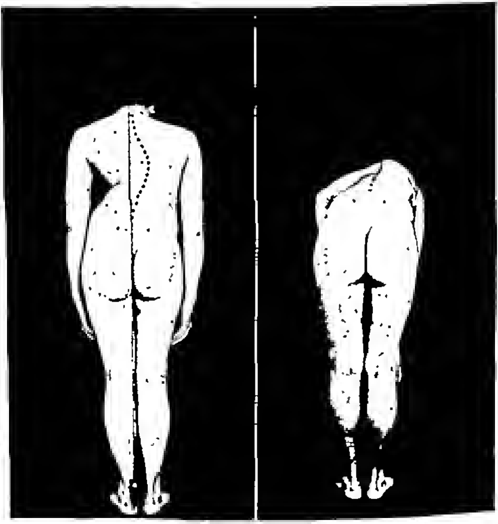
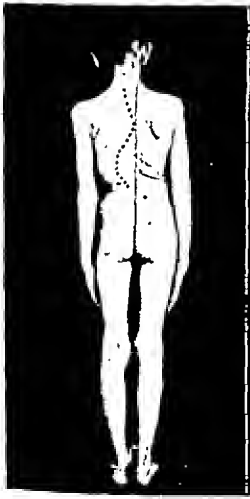


FIG. 93.—Model one year after beginning treatment. Acquisition of compensation and maintenance therapy.

FIG. 94.—Same as Fig. 93, flexed.

Moreover, the general symmetrical exercises for trunk and spinal musculature should be instituted as early as the coöperation of the patient can be secured.

At a later period in life, i.e., in the second decade, most commonly in girls at the age of 14 to 17, there occurs the common form of "round shoulders" or round back, the result of asthenia of any form and static in origin. It may be readily corrected passively and the treatment consists of posture training, symmetrical muscle training, and, in intractable types, of a brace, as described under "Scoliosis" (Fig. 33). In those in whom forward rotation of the shoulders appears to be the chief element of deformity, a simple shoulder strap may suffice (Fig. 116). The outlook in the static form, if exercises and training are persistent, is good for the ultimate correction of the tendency.



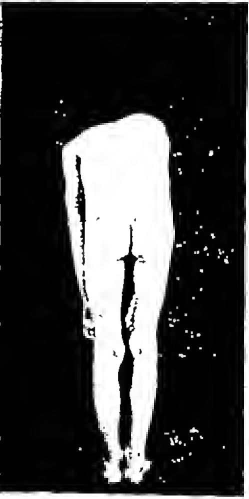


FIG. 100—Marked deformity, structural, treated with brace only.
FIG. 101—Same as Fig. 100, flexed.

d. Tuberculosis
e. Congenital malformation of the vertebrae

In infancy there is little or no physiologic lordosis in the lumbar region. This is acquired gradually, as sitting up is acquired, and is increased upon standing and walking. But in infancy, if the child is rachitic or if there is general muscular atony, the back is inclined to assume an attitude of general backward curve; in other words, the whole trunk has "slumped" forward. To prevent such a deformity from becoming confirmed, it is better to discourage sitting until general rachitic treatment has improved the underlying factor. In such cases a light corset reënforced posteriorly to support the usually pendulous abdomen and to maintain the spine erect should be worn, and upon walking the light brace illustrated in the section on scoliosis (Figs. 32 and 33) should be utilized.

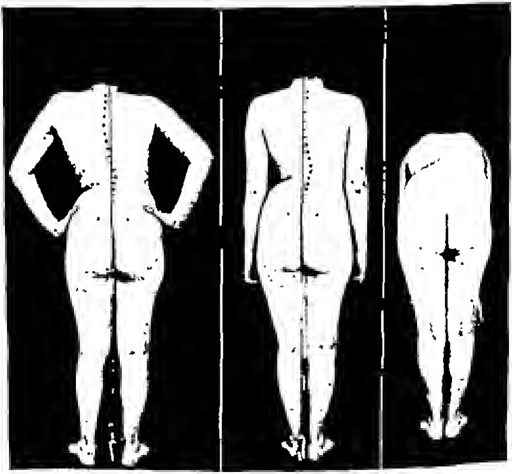


Fig. 97.—Same as Fig. 95, shifting.
Fig. 98.—Realigned and compensated by physical therapy alone.
Fig. 99.—Same as Fig. 98, flexed.

chest is deep, but the muscles are strong and no disability results; in girls more often the patient becomes asthenic and goes through life in semi-invalidism, when untreated.

This entity is evidently the result of an atypical or pathologic process of ossification of the epiphyses of the bodies of the vertebrae. In the growth of the longitudinal thickness of each vertebra there appears at the upper and lower articular surfaces a disc of bony ossification which is first noted at the age of 13 or 14. This disc gradually increases in thickness and unites when the individual is at the age of

Fig. 104.—Scoliosis due to dystonia musculorum.

22 or 23 or when the body completes its growth. In those children developing the above-described deformity, these discs become irregular and sometimes *fragmented*, suggesting the nature of the changes seen in the growing femoral capital epiphyses in Legg's (Perthes') disease and the carpal navicular in Koehler's disease. Even untreated ossification goes on and is ultimately completed, but the result is the unalterably fixed round back. Early in the disease there is sufficient resiliency to enable correction, which, however, becomes *progressively* more re-

Much more difficult is the dorsum rotundum in children of this same age which has as its origin a disorder of the growth of the vertebrae. The back gradually and painlessly assumes the attitude of excessive convexity of the dorsal spine and this convexity is fixed, i.e., cannot be passively or actively corrected. The head is thrust forward and in a compensatory effort to maintain balance the lumbar curve becomes accentuated. Thus there is the picture of round back above and "sway back" or hollow back below (Figs. 117 and 118). The shoulders are narrow and the abdomen sags. Thus there is assumed the "habitus ptoticus" with flattening of the chest, descent of the diaphragm, limitation of respiratory excursion, and abdominal visceral ptosis with its train of disorders. Not uncommonly, in boys the disorder becomes arrested; the back remains round and fixed and the

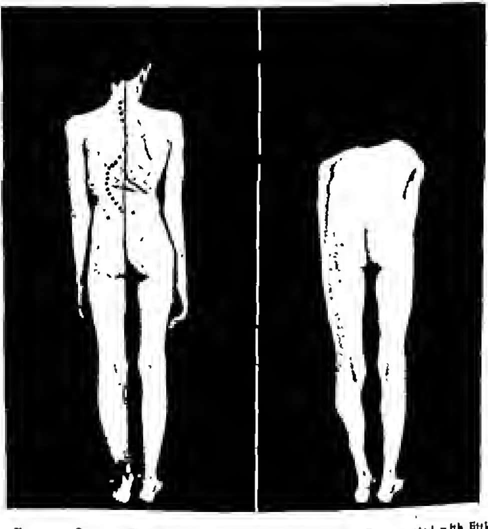
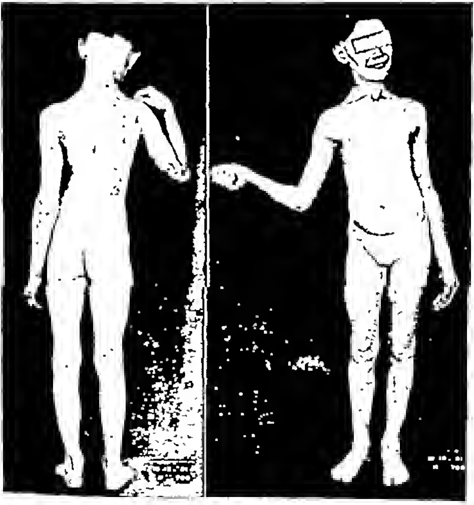


FIG. 102.—Same as Fig. 100. After 2 years with brace only. Compensated with little or no treatment.

FIG. 103.—Same as Fig. 102, flexed.

c. Later muscle training
d. General treatment of underlying cause
e. Radiation, violet rays

2. In adolescence:
   Congenital
   Static
   Postural
   a. Symmetrical muscle training
   b. Swimming
   c. Corset, brace, or shoulder straps
   Osteochondritic
   a. Same as a, b, and c under "1"
   b. Recumbency and traction, if needed
   c. Special passive and active exercises

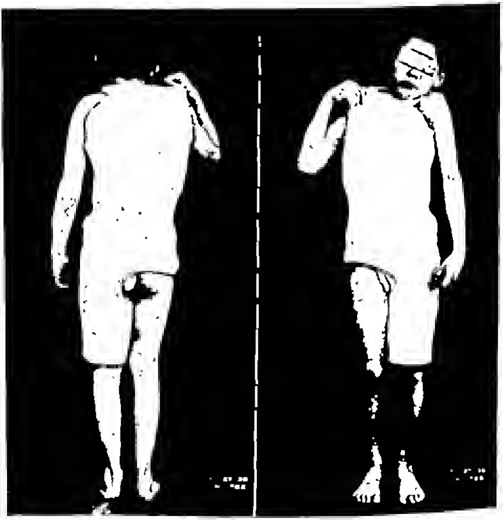


FIGS. 107 and 108.—Same as Fig. 106 after subsidence of dystonia musculorum.

sistant with time. It would appear that this pathology may be rather acute in its onset, causing pain in the back, fatigue on little exertion, and sometimes pain on movement, and it may thus be confused with early tuberculosis or other disease. On the other hand, it may be of such gradual development as to be unnoticed except for the deformity. Moreover, it may be diffuse, affecting all the spinal elements, or it may be localized in two or three vertebrae. In the former deformity will be general; in the latter it may be angular to the degree of localized gibbus.

Treatment.—This may be epitomized as follows:

1. In infancy:
   Rachitic
   Amyotonic
   a. Recumbency
   b. Corset supports



FIGS. 105 and 106.—Same as Fig. 104, in plaster.

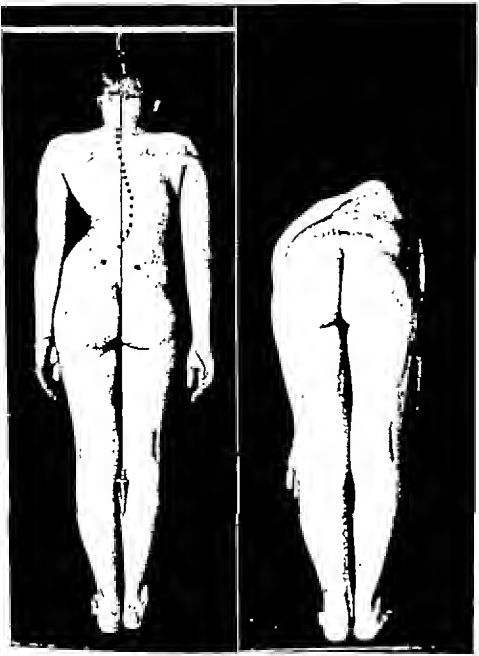


FIG. 111.—Same as Fig. 110, after operative fusion of the spine.
FIG. 112.—Same as Fig. 111, flexed

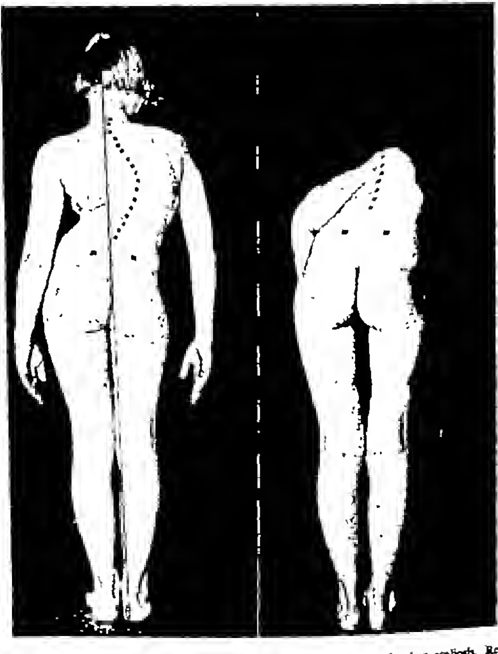


FIG. 109.—Broken compensation. Severe right structural dorsolumbar scoliosis. Relapsed after conservative treatment. Incapable of retention. Suitable for fusion.

FIG. 110.—Same as Fig. 109, flexed.

Recumbency and traction having corrected the deformity, the problem is to maintain it. This is accomplished by braces of the types illustrated (Figs. 32-33).

Muscle Training.—In the case without pain, which is the usual type, the treatment consists of general muscle training of spine and trunk and special active and passive corrective procedures. The régime is directed toward the reëstablishment of general muscle tone, and hence support; passive correction of the posterior convexity of the dorsal spine and anterior convexity of the lumbar spine, and incidentally retraction of the abdomen; and elevation of the diaphragm and expansion of the chest. The passive corrective procedures are really applied under the physical therapist's direction by the patient

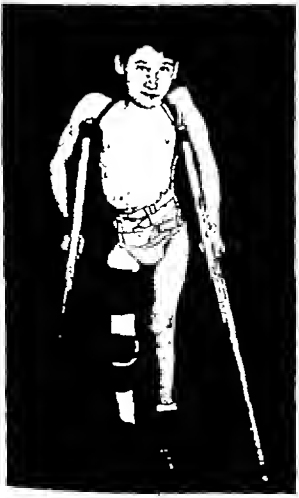


Fig. 115.—Same as Figs. 113 and 114. Striking corrective influence of crutches.
Fig. 116.—Simple shoulder apparatus in round shoulders.

3. In adults:
   Arthritic
   Traumatic
      a. Recumbency in Bradford frame, plaster dressing, traction
      b. Brace
      c. After quiescence, heat, massage, muscle training

Tuberculosis and other infections causing deformity are discussed elsewhere. Herewith is treated only the dorsum rotundum of adolescence due to vertebral disorder of growth referred to above. The principles are the same as in any anteroposterior deformity of the

FIG. 113.—Marked attitudinal and paralytic scoliosis.
FIG. 114.—Same as Fig. 113, from behind.

spine. First of all, if pain is present, all procedures involving movement, either active or passive, are contraindicated. Second, if pain is absent but is caused by movement, the latter is contraindicated. Third, if pain is absent on active or passive movement, then movements both active and passive are essential in the treatment.

RECUMBENCY AND TRACTION.—In the presence of round back with pain, tenderness, or instability, primary treatment consists of recumbency on the Bradford frame with head and pelvic traction (Fig. 47). Thus can deformity be gradually and painlessly corrected, and quiescence of the painful element can be encouraged.

himself and are therefore not purely passive but are the more effective for that reason. The useful procedures for the purpose are as follows:

1. Direct Vertical Traction on the Rings, Accompanied by Swinging. This elevates the shoulders, flattens the abdomen, pulls upon the chest wall through the thoracicohumeral musculature, and tends to exert traction on the round back (Fig. 119).

2. Standing Backward Shoulder Stretching. The patient, standing in a corner with hands applied to walls, bends forward and pushes forward with lower extremities. This pushes the shoulders backward upon the thorax and expands the chest anteriorly (Figs. 120 and 121).

3. Recumbent Stretching on Roll under Round Back. A thick felt pad or roll is placed beneath the dorsal spine with arms behind the head. Arms and head above and trunk below exert leverage upon the dorsum rotundum as the fulcrum (Fig. 122).

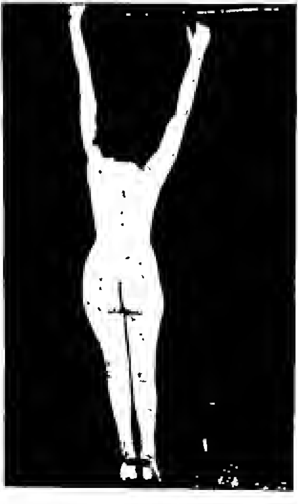


FIG. 119.—Round back exercises. Hanging and swinging on the rings.

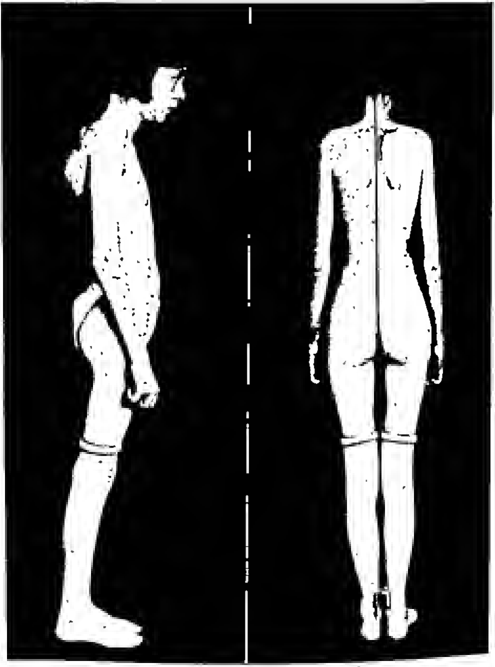


FIG 117.—Dorsum rotundum due to osteochondritis vertebrae or epiphysitis vertebrae.
FIG 118—Same as Fig. 117, posterior view.

himself and are therefore not purely passive but are the more effective for that reason. The useful procedures for the purpose are as follows:

1. Direct Vertical Traction on the Rings, Accompanied by Swinging. This elevates the shoulders, flattens the abdomen, pulls upon the chest wall through the thoracicohumeral musculature, and tends to exert traction on the round back (Fig. 119).

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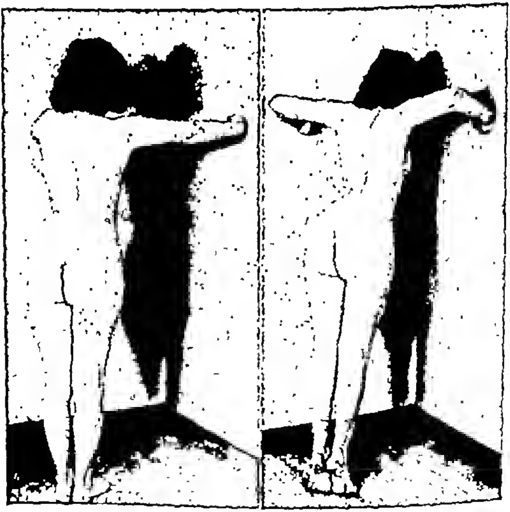
Fig. 119.—Round back exercises. Hanging and swinging on the rings.

4. *Abdominal Retraction.* With the same position as in "3," the abdominal musculature is retracted sufficiently to flatten the lumbar curve. This exercises the abdominal muscles, expands the chest, and increases the leverage on the dorsal spine (*Fig. 123*).

5. *Dorsal Flexion against Round Back.* In the prone position with the strap applied over the summit of the dorsal curve, head and shoulders are actively dorsiflexed, thus exerting passive corrective influence on round back and strengthening the extensor musculature (*Fig. 124*).

6. *Standing Table Exercise.* The patient stands forward-flexed at hips, with trunk upon a table, arms extended above, grasping a staff. While maintaining contact between abdomen and table, arms are extended with staff over the head, staff is brought into contact with round dorsal spine, and backward leverage is exerted by further extension of curved dorsal spine. Thus the lumbar curve is flattened, the



FIGS. 130 and 131.—Standing, stretching shoulders backward.

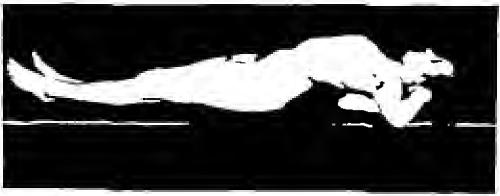


Fig. 122.—Recumbent stretching on roll under round back.

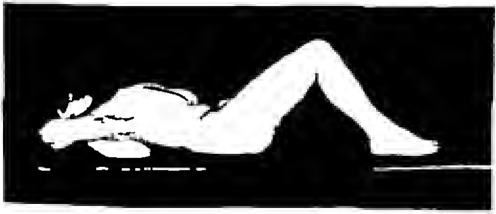


Fig. 123.—Abdominal retraction.

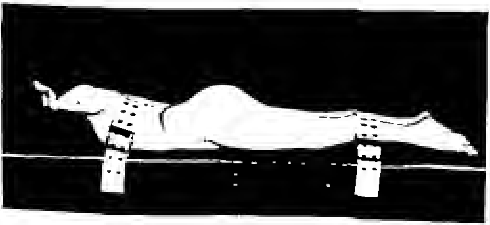
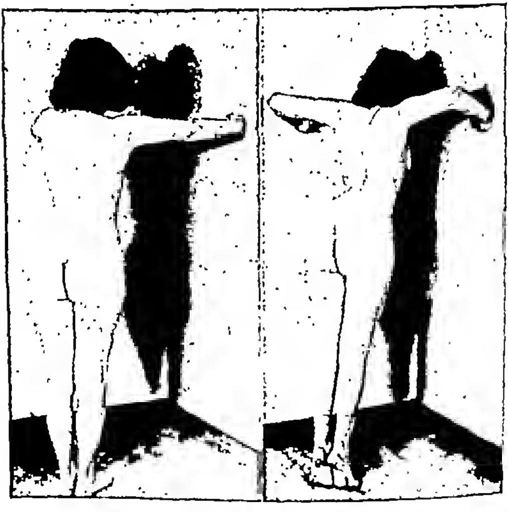


Fig. 124.—Dorsal flexion against round back.

4. Abdominal Retraction. With the same position as in "3," the abdominal musculature is retracted sufficiently to flatten the lumbar curve. This exercises the abdominal muscles, expands the chest, and increases the leverage on the dorsal spine (Fig. 123).

5. Dorsal Flexion against Round Back. In the prone position with the strap applied over the summit of the dorsal curve, head and shoulders are actively dorsiflexed, thus exerting passive corrective influence on round back and strengthening the extensor musculature (Fig. 124).

6. Standing Table Exercise. The patient stands forward-flexed at hips, with trunk upon a table, arms extended above, grasping a staff. While maintaining contact between abdomen and table, arms are extended with staff over the head, staff is brought into contact with round dorsal spine, and backward leverage is exerted by further extension of curved dorsal spine. Thus the lumbar curve is flattened, the



Figs. 120 and 121—Standing, stretching shoulders backward.

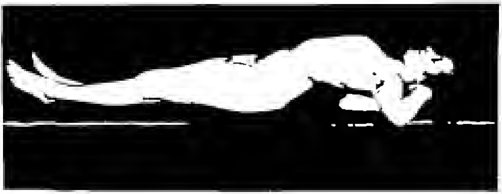


Fig. 122.—Recumbent stretching on roll under round back.

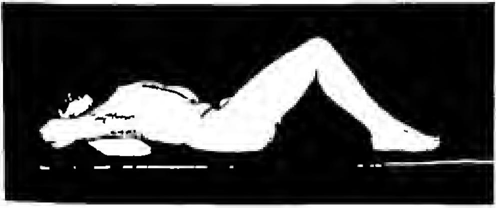


Fig. 123.—Abdominal retraction.

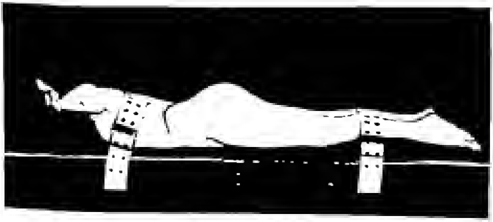
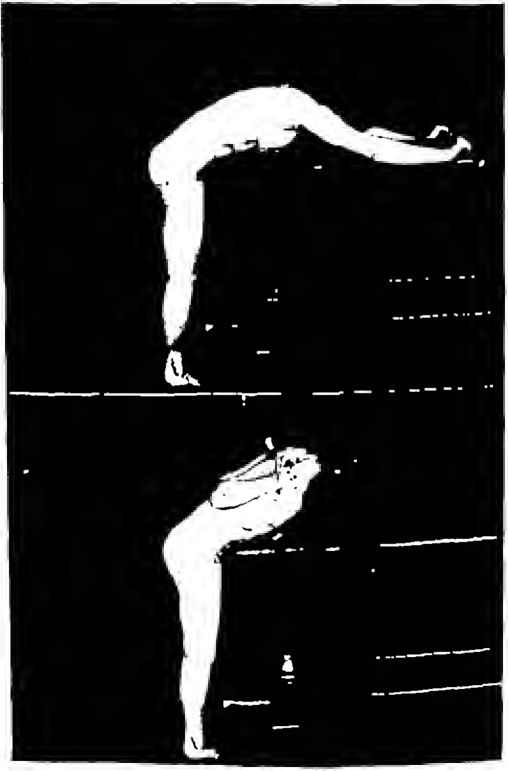


Fig. 124.—Dorsal flexion against round back.



FIGS. 115 and 116.—Standing, table exercise.

dorsal curve is decreased, and the spinal musculature is strengthened (Figs. 125 and 126).

All these exercises are to be carried out slowly and gracefully within the limits short of fatigue, and they are supplemented by swimming and general calisthenics. They are simple enough to enable the patient to learn the routine and to carry them out at home twice daily. Moreover, the child must be impressed with the necessity of maintaining the attitude of maximum correction at all times, and when he is unable to do so, this effort must be supplemented by apparatus.

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CHAPTER EIGHTEEN

TREATMENT OF MALIGNANCIES OF THE SKIN

George M. MacKee, M.D., and Anthony C. Cipollaro, M.D.

CANCER OF THE SKIN AND ORIFICIAL MUCOUS MEMBRANES

Foreword

Throughout this chapter the various physical agents used for the treatment of cancer of the skin and orificial mucous membranes, and for the treatment of conditions that might lead to cancer, are mentioned but are not described. A detailed description of these methods and agents is given in Chapter 18, Volume I, and Chapter 4, Volume III. Technical details contained in those chapters are not repeated here. Also many terms are used in this chapter for which no definition is given. Explanations for these terms are contained in the chapters mentioned above.

The family physician, for whom this chapter is written, is often the first to be consulted by a patient who has cancer or who has a condition that may lead to cancer. It is important, therefore, for the practitioner of general medicine to be well acquainted with the clinical aspects of these conditions. Many general physicians are excellent surgeons, using either the scalpel or surgical diathermy, or both. Only experts in the use of roentgen rays and radium are qualified to use these agents in the treatment of cancer; but every physician should know what is being accomplished with these agents.

For the reasons enumerated above, considerable attention is given to clinical description, and to therapeutic methods that are employed by physicians other than specialists. A few statistics are included. The discussion of roentgen-ray and radium therapy in relation to the cancer problem is general. This discussion gives information with which the family physician should be familiar. It must not be construed as an attempt to teach the technic of such therapy nor to encourage the use of these agents by general physicians. The bibliography contains references for those who are particularly interested in roentgen-ray and radium treatment.

Mortality and Incidence of Cutaneous Cancer

The incidence and death rate of cancer increased markedly in New York City between the years 1910 and 1930. Statistics for New York City may be taken as a barometer for other large urban centers in the United States. Several factors are apparently responsible for this increase, the most important being the longer expectancy of life. Cancer is most prevalent after the age of 40, and a much larger proportion of the population now reach the later decades than was formerly the case. Improved methods of diagnosis, cancer propaganda and education (directed at both the medical and lay public), and better statistics are other factors which influence the incidence and death rate.

The death rate can be ascertained with a fair degree of accuracy. In New York City the death rate from cancer was 78 per 100,000 of population in 1910. In 1930 the rate had increased to 117 per 100,000 population. The actual number of deaths from cancer in New York City during the year 1930 was 8,025.[1]

When cancer as a cause of death in New York City is compared with other diseases, it is found to rank second to heart disease, to equal pneumonia and to be far above tuberculosis. Succinctly, the death rate per 100,000 population for heart disease (for 1930) was 244; for cancer, 117; for pneumonia, 116; for tuberculosis, 64.

Of the total of 8,025 cases of cancer that terminated fatally and appeared on the death certificate as the cause of death in New York City in 1930, 363 (4.52 per cent) were cancers of the skin and buccal cavity. The tumors in these 363 patients were located as follows: cancer of the buccal cavity—males, 229; females, 28 (3.20 per cent). Cancer of the skin—males, 66; females, 40 (1.32 per cent).

In the registration area of the United States, there were 76,274 deaths from cancer and other malignant tumors (mostly cancer) in 1921. Of these, 2,610 (3.42 per cent) were cancers of the mouth, 2,132 occurring in males and 478 in females. Two hundred and eighty-seven deaths (0.38 per cent) were due to cancer of the vagina and vulva. Malignancy of the skin was given as the cause of death in 2,433 cases, or 3.19 per cent.

Since cancer is not a reportable disease, it is impossible accurately to determine its incidence. Also, at the present writing, it is impossible to ascertain the total number of cases of cancer of the skin and orificial mucous membranes that have been cured.

The point to be emphasized here is that approximately 7 per cent of deaths due to cancer in the United States (1921 statistics) are caused by cancer of the skin and orificial mucous membranes. In one year (1930) there were 363 deaths in New York City caused by cancer of these parts.

As we shall see later, the therapeutic results in cases of advanced metastatic cancer are encouraging; in certain morphologic and cytologic types of such growths the results are excellent. However, there is

no certain cure for unselected cases of advanced cancer, hence the large mortality. Cancer in a very early stage of evolution, before metastasis has occurred, is usually curable. Obviously, therefore, if every case of cancer could be diagnosed sufficiently early and adequate treatment immediately instituted, there would be a spectacular drop in cancer fatalities. Such a desirable attainment is very often impossible in the case of cancer of the viscera and other deep structures. But it is possible in the majority of cases of cancer of the skin and orificial mucous membranes. It is even possible to accomplish more than this. Many cutaneous cancers develop as a result of a long-standing antecedent lesion. These potentially dangerous lesions are well known and will be described later. Most of them can be permanently eradicated. If all or the majority of such conditions were recognized and destroyed, there would be a substantial reduction in cancer incidence.

The dermatologist can usually make a clinical diagnosis of early cutaneous cancer and of conditions that may lead to cancer. When this is impossible, a microscopic examination may help to establish the diagnosis. The practitioner of general medicine cannot be expected to make all the necessary clinical differentiations between cancer or dangerous cutaneous lesions and the large number of benign conditions which they may simulate. Proper undergraduate and postgraduate instruction in dermatology, with sufficient emphasis on the conditions under consideration, will increase the diagnostic ability of the physician. Periodic health examinations will give the family physician opportunity to examine the entire cutaneous surface and the membranes of the orifices. The family physician really should be able at least to detect dangerous lesions of the skin and membranes, and to suspect the potentialities. He may then request a consultation or microscopic examination, or eradicate the condition, according to his training, ability, facilities and willingness to assume responsibility.

When dealing with *malignant growths* or *conditions that may* lead to such growths, the situation is so serious—i.e., it is so essential that no diagnostic or therapeutic error be made—that it seems advisable for the family physician to request a division of responsibility.

In recent years several organizations have conducted a determined and comprehensive campaign of cancer education in an attempt to reduce the incidence and mortality of the disease. This campaign has undoubtedly accomplished a great deal of good. It is probable that a continuation of the cancer propaganda directed at the lay public will prove helpful, especially if very carefully done. It seems advisable to teach the public, with carefully selected words, that cancer is amenable to treatment and that it is often preventable. Rather than attempting to teach symptomatology, which so often proves injurious, it seems preferable constantly to urge periodic health examinations. These organizations can help to educate the medical public by continuing to suggest adequate instruction for the undergraduate medical student,

and suitable postgraduate courses, seminars, symposiums, addresses, articles, monographs and books for the practicing physician.

Cutaneous Conditions That May Give Rise to Cancer

The lesions and conditions of the skin and orificial membranes that frequently and occasionally give rise to cancer are known as the precancerous dermatoses. The term is a poor one because it implies a necessary sequence, whereas in reality even the most dangerous members of the group do not always give rise to cancer, and many of the so-called precancerous dermatoses are hardly more dangerous than is normal skin. There are pathologists, dermatologists and cancer experts who aver that there is always a precancerous stage to every cancer. Often the precancerous condition is visible to the naked eye. At times it can be detected only with the aid of a microscope. In support of this contention are the so-called nonpigmented melanomas which have been shown to arise in defects that are not macroscopic; also the so-called nevus tardus—a birth mark which presumably must be present at birth but which does not become visible for weeks, months or many years after birth.

Without delving deeper into the academic aspect of this controversial subject, suffice it to say that dermatologists employ the term *precancerous dermatoses* simply for a convenient sobriquet for a certain group of conditions for purposes of conversation and teaching. When teaching medical students or addressing a medical group the exact meaning or significance of the term is explained.

As indicated above, the precancerous dermatoses include conditions that frequently give rise to epidermoid carcinoma, either spontaneously or as a result of irritation. Among such conditions are leukoplakia, kraurosis vulvae, senile keratosis, certain roentgen-ray and radium injuries, the blue-black mole and so on. At the other extreme are relatively benign conditions such as a long-standing ulcer, a large scar, and a large number of cutaneous lesions. Any permanent elevation above the normal surface of the skin, such as a small scar, a common mole or even a wart, if frequently irritated or traumatized, as might happen on the bearded region of an adult male, might lead to cancer. An area of gum constantly irritated over a period of many years by a ragged tooth might also give rise to cancer. Such conditions are comparatively free but not entirely free of danger. It is for this reason that these and many other more or less similar conditions are included in the group of precancerous dermatoses.

Alphabetical List of Forerunners of Cutaneous Cancer

Cicatrix
Cornu cutaneum
Erythroplasia

Farmers' skin (sailors' skin)
Inflammatory dermatoses:

Eczema
Lichen planus
Psoriasis

Keratoses:

Arsenical
Seborrheic
Senile
Occupational:

Tar, pitch, oil, carbon, etc.

Kraurosis vulvae
Leukoplakia
Lupus erythematosus
Lupus vulgaris
Nevi
Papilloma of tongue
Radiodermatitis
Sebaceous cyst
Syphilis (syphilitic leukoplakia, smooth atrophy and interstitial glossitis)
Ulcers (long standing)
Von Recklinghausen's disease (multiple neurofibromatosis)
Xeroderma pigmentosum

Paget's disease and Bowen's precancerous dermatosis have heretofore been included among the precancerous dermatoses. They are excluded here because Pautrier,[2] Massia and Rousset,[3] Fraser,[4] and many others who have made careful studies of these conditions, find that they are cancer from the beginning. Massia and Rousset state that: "One is forced to the hypothesis that both affections are cancerous from the beginning, and that their origin cannot be other than in the epithelium of the skin or the demi-mucosae in such regions as the nipples, glands, vulva, anus, axilla, etc." The subject is under controversy, but the majority of those who have investigated the two diseases agree with the opinion expressed by Massia and Rousset.

CICATRIX

Cancer not infrequently develops in scar tissue, especially in large scars resulting from extensive third degree burns, destructive diseases such as syphilis and tuberculosis, and severe injuries. Small scars, even when keloidal or hyperplastic, are not considered dangerous unless *frequently traumatized*. The new growth may be sarcoma, but it is

FIG. 1.—Squamous-cell epithelioma developing in a scar.

usually epithelioma of the squamous-cell variety. Epithelioma, when developing in scar tissue, usually evolves slowly probably because of the dense sclerotic tissue. But when the growth invades normal tissue it is apt to be rapidly invasive and metastasis soon occurs. Cancer occurring in scars from burns used to be called Marjolin's ulcer.

Small, slightly elevated scars that are frequently traumatized may be excised and primary union obtained. If there is a keloidal idiosyncrasy, hyperplas' ı can often be prevented by the postoperative applica-

tion of roentgen rays or radium. At times the elevated scar can be reduced to the level of normal skin with these agents without resorting to surgery; or the elevated portion may be removed with surgical diathermy, especially with a loop electrode, radium and roentgen rays being used subsequently to prevent hyperplasia. We are discussing small elevated scars such as may occur on the bearded region of the male adult and which may be cut frequently with the razor. Such scars, when not subjected to frequent irritation or traumatism over a long period of time, are probably no more dangerous than is normal skin. Any or all of the therapeutic procedures mentioned above may fail. In such a case the lesion may be therapeutically neglected and inspected once or twice yearly, or a plastic operation may be performed.

Large scars should be inspected by the family physician at least once a year, or the patient should be instructed to consult his physician in case there is any change in the scar. Ulcers, either spontaneous or traumatic, which occur in scar tissue and which do not heal in a few weeks under the influence of conventional treatment, should, from a clinical standpoint, be regarded as the possible early stage of cancer. In such instances it is well to make a microscopic examination. Even without proof of cancer, when the ulcer refuses to respond favorably to the various kinds of medicinal and physical therapy remedies recommended for chronic ulcers, it seems preferable to perform a plastic operation and remove the danger.

CORNU CUTANEUM (CORNU HUMANUM)

The hypertrophy known as the cutaneous horn was so named because of a faint resemblance to the horns of cattle. Usually the condition is classified with the keratoses and warts. The pathologic change, however, is not always that of a keratosis or of a wart. At times the arrangement of cells suggests a corn. Like the senile keratoses, the cutaneous horn is encountered most frequently in the later decades of life, but it is seen occasionally in children.

Cutaneous horns occur most frequently on the face and scalp, less frequently on the penis, scrotum, buttocks and other parts. They are usually single. In shape they may be conical, cylindric, straight, twisted, angular, or otherwise. They may be of almost any color, most commonly yellowish-brown or brownish-black. They may be short or several inches in length. In size they vary from a tiny lesion suggestive of a filiform wart to one having a circumference of 14 inches, as reported by Rodriguez.[7] The base of the lesion is usually verrucous; the greater part of the lesion is composed of keratin. Occasionally, they shed spontaneously never to return; recurrence, however, is the rule. Lebert[8] estimates that about 12 per cent of cutaneous horns change to cancer.

It is advisable to destroy cutaneous horns. Small lesions may be extirpated after being softened with a 10 per cent solution of caustic

FIG. 2.—Cutaneous horn.

potash. Trichloracetic acid may then be applied to the base. A more certain and more popular method of destruction is with electrodesiccation. When carefully done, the result is permanent and there is either no scar or one that is inconspicuous. When preferred, the lesion may be excised. Solid carbon dioxide, radium and roentgen rays have been employed with good results by some.

ERYTHROPLASIA

(Épithéliome papillaire nu)

Erythroplasia is an uncommon affection. It was first described by Fournier and Darier [6] in 1893. Queyrat [24] made a careful study of this condition in 1910 and since then, in this country, the affection has been known as erythroplasia of Queyrat. Sulzberger and Satenstein [25] reported the first American case.

The affection attacks especially the glans penis, but may also occur on the orificial mucous membranes. At first there may be one or several small lesions which gradually extend peripherally. At first only hyperemia may be visible with little edema, thickening or elevation. Later there develops definite infiltration. The surface is shiny or velvety and there may or may not be a serous exudate. Stinging and itching may be present.

Erythroplasia can be considered as a true precancerosis, since in every instance when the patient has been observed for a sufficiently long time, prickle-cell epithelioma with involvement of the lymph nodes has developed. The disease is likely to be mistaken for eczema, syphilis, epithelioma, moniliasis, psoriasis and tuberculosis.

The etiology is unknown and the histology shows at first acanthosis, hyperkeratosis, parakeratosis and inflammatory changes. Later dyskeratotic changes of a Bowenoid type occur and eventually infiltrating prickle-cell epithelioma develops.

Treatment consists in complete destruction of the lesions by scalpel or electrosurgery. Amputation of the penis is necessary in some cases. *Topical remedies, x-rays and radium have failed.*

INFLAMMATORY DERMATOSES

It has been reported that several of the inflammatory dermatoses, such as eczema, psoriasis and lichen planus, have become carcinomatous. The consensus of opinion among dermatologists, however, is that the neoplasm develops secondary to a keratosis caused by radiodermatitis or arsenotherapy, or both. It is improbable that these dermatoses, per se, ever give rise to cancer except, perhaps, in the case of long-standing lichen planus of the mouth. Saad[9] reports a case of buccal lichen planus of three years' duration in which carcinoma developed.

FARMERS' SKIN (SAILORS' SKIN)

This condition occurs on the exposed parts of middle-aged and elderly persons who have been exposed to the sun for many years

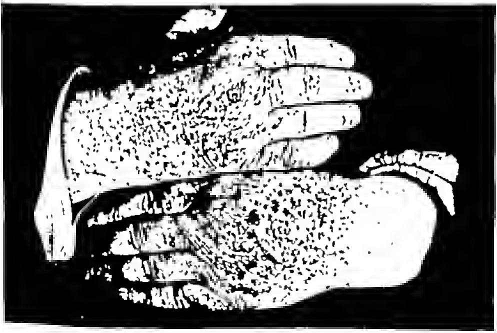

FIG. 3.—Farmers' skin (sailors' skin) showing atrophy, "permanent freckles," senile keratoses and a squamous-cell epithelioma.

and who have a low actinic toleration. The skin becomes wrinkled and dry; permanent lentigo (freckles) and keratoses develop. The condition bears some resemblance to chronic radiodermatitis, senile

skin, and xeroderma pigmentosum. It is quite common for epithelioma to develop in farmers' skin. The epithelioma may be of the basal-cell or squamous-cell type. Squamous-cell growths, when occurring in such skin, are often of comparatively low malignancy. The present fad for sun bathing and the use of sources of intense ultraviolet radiation in the home may possibly cause a numerical increase of cases of farmers' skin in the future.

Treatment consists of avoiding direct and strongly reflected sunlight or adequate protection against such light. Protection may be obtained by the use of a walnut stain, or by rubbing a dark-colored cream into the skin followed by the application of a dark-colored powder.

℞ Ichthyol .... gr. v
Carmine .... gr. ss
Burnt sugar .... ʒss
Zinc oxide .... ʒii
Starch (rice) .... ʒiii
Vaselin (white) .... ℥i
Lanolin .... ʒiii
M. Sig.: Apply to exposed parts for protection against sunlight.

℞ Cosmetic brown .... gr. viii to xv
Lanolin, anhydrous .... ʒii
Zinc oxide .... ʒi
Bismuth subcarbonate .. ʒii
Magnesium carbonate .. ʒss
Talc .... ʒss
Starch (rice) .... ʒii
M. and pass through fine sieve.
Sig.: Apply to exposed parts after using the cream.

An ointment consisting of equal parts vaselin and lanolin with 10 per cent zinc oxide, applied to the skin just before exposure to the sun, provides sufficient protection in many cases. After the ointment has been rubbed into the skin, powdered talc may be applied. The following cream may be applied so thinly as to be inconspicuous and yet give adequate protection.

℞ Salol .... gr. v.
Tannic acid .... ʒss
Cold cream ......q.s. ad ℥i
M.

Patients with well-developed farmers' skin should have the involved areas inspected at least once a year. It is well to destroy the keratoses with electrodesiccation. An ointment, such as the one subjoined, may be rubbed into the skin at night to combat the excessive dryness, also an almond emulsion may be applied several times daily.

℞ Lanolin, anhydrous..... ʒii
Olive oil .... ʒi
Vaselin .... ʒii
Cold cream ......q.s. ad ℥i

KERATOSES

The lesions known as the keratoses are among the most common and most frequent of the forerunners of cancer. The keratoses that will be discussed here are the senile keratosis, seborrheic keratosis, arsenical keratosis and the industrial keratosis.

Senile Keratosis.—The senile keratosis is seen most commonly on the face and the backs of the hands in persons past middle life. They

are perhaps more common in light than in dark skin. They are seldom encountered in negroes, American Indians and Arabs. The clinical appearance depends on the stage of development. The lesions range in size from the head of an ordinary pin to a silver quarter, and occasionally larger. They consist mainly of a thickened horny layer, or scale, which is firmly adherent. The scale may occasionally exfoliate, which gives the impression of improvement. It is unusual for an untreated senile keratosis to disappear permanently. The lesions may be very slightly elevated or considerably so, depending on the amount of hyperkeratosis and inflammatory changes. When the lesion consists of more than a thickened horny layer, one should suspect the early stage of epithelioma; that is, if there is any evidence of acanthosis, or infiltration—any thickening other than that produced by the scale.

The senile keratosis is a dangerous lesion, especially when situated on the mucous surface of the lip. Many of them change to epithelioma sooner or later. It is probable that the neoplasm is always of the squamous-cell type when situated on the mucous surface of the lip. When the keratosis is situated in the skin, the resulting epithelioma is usually of the squamous-cell type. Eller and Ryan [10] state that it is always of the squamous-cell type.

Senile keratoses of the lip so frequently give rise to cancer that we advise the destruction of all such keratoses as soon as detected. Whether or not a given senile keratosis of the skin should be destroyed is a matter of judgment. As a general rule it is preferable that they be eradicated, especially when the patient has a reasonably long expect-

FIG. 4.—Senile skin showing atrophy, "permanent freckles" and both senile and seborrheic keratoses.

ancy of life. A very old person may have one, several or many lesions. In such instances it is often advisable to keep the patient under observation and treat only the lesions that appear to be changing from keratosis to cancer. Many senile keratoses never give rise to cancer. When cancer does develop on a senile keratosis, the evolution is usually slow so that the physician has plenty of opportunity to detect the transition, provided the patient remains under observation.

One of the best treatments for senile keratosis is electrodesiccation. The area is first cleansed properly, then procainized. The lesion is next thoroughly dehydrated with the electrodesiccating current. The mummified tissue is removed with curet or scissors, and the base of the wound is again electrodesiccated. When there is the slightest suspicion of epithelioma, the treatment is, of course, that advised for malignant neoplasms. Many persons, especially society women with lesions on the face, prefer to avoid scars or any permanent defect such as depigmentation. However, when treating a senile keratosis it is advisable to concentrate on a permanent cure rather than on avoiding a permanent defect. Radium and roentgen rays are efficacious, when properly applied, for selected cases. The same statement may be made for solid carbon dioxide, the electric cautery, and various caustics. Persons who have a tendency to develop senile keratosis on the mucous membrane of the lip and on the skin should avoid excessive exposure to strong actinic light, and it is well to apply ointments and creams frequently.

Seborrheic Keratosis.—As a rule seborrheic keratoses are divided into two main varieties—hyperkeratotic and nevoid. The *hyperkeratotic* variety will be described first. This type of keratosis is most common on the face, scalp and trunk. Seborrheic keratoses may develop as early as the third and fourth decades, but they are far more common in middle-aged and elderly persons. They are, perhaps, more common on very oily (seborrheic) skins. In size, they correspond with the senile keratosis. The color is usually dark brown. The scale is usually waxy or greasy and, as a rule, it can be rather easily removed. The scale often sheds spontaneously but almost invariably recurs. The lesions are well circumscribed and only slightly elevated as a rule. Occasionally, one encounters a seborrheic keratosis that is verrucous.

The seborrheic keratosis is not very dangerous. Some dermatologists aver that they never give rise to epithelioma. The majority of dermatologists, including the writers, are of the opinion that an unknown percentage of these lesions do give rise to epithelioma which, however, is usually of the basal-cell type.

Obviously, it is important to distinguish between a seborrheic and a senile keratosis. Usually they can be differentiated clinically by the gray, dry, adherent scale of the senile keratosis, as compared with the dark-brown, waxy, removable scale of the seborrheic keratosis. At times it is impossible to make the distinction. In such instances it is

preferable either to regard the lesion as of the senile type or to make a microscopic examination.

From the standpoint of danger it is not necessary to remove seborrheic keratoses, provided the lesions are occasionally inspected. As a rule, however, it is preferable to destroy them in order to prevent possible development of basal-cell epithelioma, and even squamous-cell epithelioma, and, also, for cosmetic reasons. When situated on the exposed parts, especially in women, it is advisable to avoid leaving a scar if possible.

In the early stage of evolution it is possible permanently to remove many lesions simply by the application of trichloracetic acid. When the scale is quite thick, it is preferable first to remove the horny layer with a curet and then apply the acid. Often this can be done without a local anesthetic. Radium is frequently efficacious but recurrences are common. When carefully applied, the lesion is apt to disappear without leaving a trace. Solid carbon dioxide is used for this purpose by some dermatologists, but it is not a popular remedy. The most popular agent and probably the one that is most certain permanently to cure the lesion is electrodesiccation.

Nevoid Keratosis.—This variety of keratosis occurs on the face and trunk of people over 30 years of age, most commonly after the age of 50. In size the lesions range from the head of an ordinary pin to a fifty-cent piece and even larger. They are sharply marginated, consid-

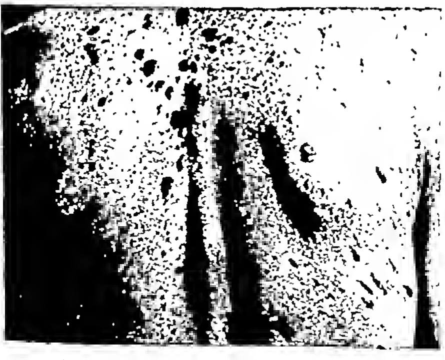

Fig. 5.—Hyperkeratotic and nevoid seborrheic keratoses.

erably elevated, usually dark brown or brownish-black in color, often shiny and smooth. Usually there is no perceptible thickening of the horny layer—no scale. They should be differentiated from nevi, which they rather closely resemble. As in the case with the other varieties of keratosis, there may be a single lesion, a few or many.

It is probable that the percentage of cases of epithelioma arising from the nevoid keratosis is small. It is also probable that the majority of such epitheliomas are of the basal-cell type.

The nevoid keratosis is not, therefore, considered a very dangerous lesion. However, inasmuch as they are unsightly and, particularly, because they may give rise to cancer, possibly of the squamous-cell type, it is customary to destroy them. Under local anesthesia the lesion is dehydrated with electrodesiccation or coagulated with electrocoagulation. It is then removed with the curet, and the base of the wound is electrodesiccated. They may also be excised. Finally, they may be let alone and inspected once yearly. Radium and roentgen rays are not very efficacious.

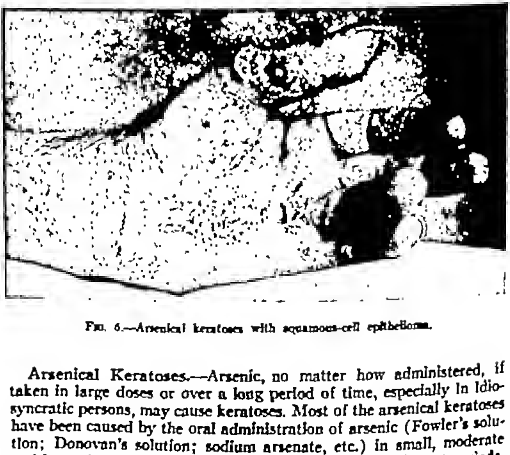

FIG. 6.—Arsenical keratoses with squamous-cell epithelioma.

Arsenical Keratoses.—Arsenic, no matter how administered, if taken in large doses or over a long period of time, especially in idiosyncratic persons, may cause keratoses. Most of the arsenical keratoses have been caused by the oral administration of arsenic (Fowler's solution; Donovan's solution; sodium arsenate, etc.) in small, moderate and large doses for long periods of time without suitable rest periods. Arsenic, as a rule, should be given in courses with intervals of one

or several months between courses. Also, the patient should be carefully observed for low toleration.

The keratoses show a predilection for palms and soles. Occasionally, the affection is more or less generalized. It is often accompanied by widespread, punctate pigmentation of the trunk. The characteristic picture is excessive dryness of palms and soles with almost innumerable punctate, deep-seated keratoses. Occasionally, very large thick lesions are encountered. Both basal-cell and squamous-cell epitheliomas are prone to develop on arsenical keratoses.

The affection is treated with copious applications of grease. The patient is kept under observation, and individual keratoses that are active—that is, those that continue to evolve—are destroyed with electrodesiccation. The area should be procainized and the keratosis should be completely eradicated. In recent years it has been customary to administer intravenously a freshly prepared solution of sodium thiosulphate; but no one has yet conclusively proved that such treatment has any influence on arsenical keratoses or that the formation of additional lesions can in this way be prevented.

Industrial Keratoses (Industrial Keratoderma; Occupational Keratoderma).—Keratoses often precede the development of industrial cancer of the skin. That cancer of the skin is a problem of some magnitude in industrial medicine can be appreciated by a review of the industries in which this condition develops. Workers come in contact with tar in the following occupations: Anthracite laborers, aniline dye workers, benzine distillers, chimney sweeps, coal oil workers, creosote workers, gas-works stokers, lamp-black workers, pitch handlers, sprinklers of soot (gardeners), paraffin workers, road tar sprayers, tar distillers and many others.

Workers come in contact with arsenic in the following occupations: sheep-dip workers, workers in Paris green, those who make or handle wall paper, smelters of ores, furriers, tanners, tree and shrubbery sprayers, taxidermists, etc.

In addition to keratoses caused by tar products and arsenic, there are those occurring in persons working with roentgen rays and radium, in shale-oil workers and so on.

Persons who work in these various industries and who show a tendency to develop keratoses in spite of proper hygiene should change their occupation.

Cancer in these cases, which is usually of the squamous-cell type, is usually preceded by a long-standing follicular dermatitis or follicular keratoderma. Occasionally, keratoses of the senile type occur. The dermatitis or keratoderma may disappear with change of occupation, cleanliness and soothing topical remedies. If not, the patient must remain under observation. Keratoses, ulcers that refuse to heal, and nodules should be excised or destroyed with electrodesiccation or electrocoagulation.

erably elevated, usually dark brown or brownish-black in color, often shiny and smooth. Usually there is no perceptible thickening of the horny layer—no scale. They should be differentiated from nevi, which they rather closely resemble. As in the case with the other varieties of keratosis, there may be a single lesion, a few or many.

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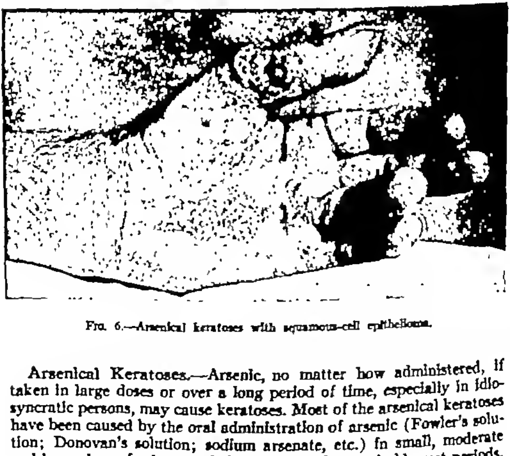

FIG. 6.—Arsenical keratoses with squamous-cell epithelioma.

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in the same manner. Small areas of leukoplakia may be destroyed with radium, the electric cautery or with electrodesiccation, the last being the most popular method for the purpose. Large areas of

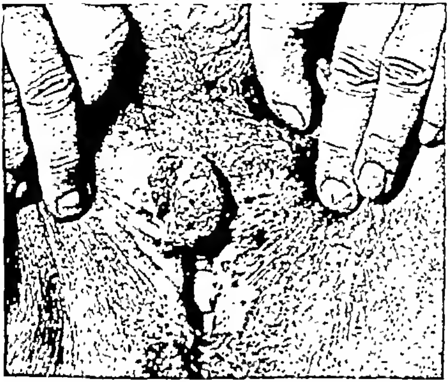

FIG. 8.—Kraurosis vulvae with squamous-cell epithelioma.

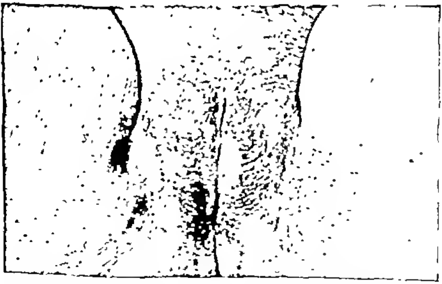

FIG. 9.—Same as Fig. 8. After surgical diathermy and roentgen-ray treatment.

KRAUROSIS VULVAE

This malady involves the mucous membrane of the female external genitalia. It seldom occurs before the age of 40 or 50. The first symptom may be a recalcitrant pruritus which becomes very annoying. The membrane becomes atrophic, sclerotic, pale, and leukokeratotic. The leukokeratotic changes are probably identical with leukoplakia of the buccal mucosa. The incidence of squamous-cell epithelioma in this affection has been estimated to be about 10 per cent.

As a rule, it is well to treat this disease conservatively and to inspect the involved parts at least every six months. Excellent local hygiene is indicated. Itching may be relieved with nonirritating topical anti-

FIG. 7.—Kraurosis vulvae showing sclerosis and leukoplakia.

pruritics such as lotions and ointments containing small quantities of menthol, butesin, anesthesin, phenol, etc. Roentgen rays may be used as an antipruritic if necessary, but such treatment should be limited to one or two short courses of fractional doses. Alcohol injections and resections of the sensory nerves of the perineum are other methods of controlling vulvar pruritus. Radium may be of value for small areas of leukoplakia. Ulcers and erosions that do not heal quickly should be excised or destroyed with the actual cautery or with high-frequency electricity, preferably the latter. Vegetations and nodules are treated

uous as a rule. The affected area may develop fissures, erosions or ulcers, or it may become verrucous or vegetating. Such lesions are especially dangerous, but it should be borne in mind that epithelioma may develop suddenly and rapidly in an apparently inactive patch of leukoplakia. When epithelioma develops in leukoplakia it is always of the squamous-cell type. As a rule, the early evolution of the cancer is slow; occasionally, it is rapid.

The affection must be differentiated from lichen planus, lupus erythematosus, aphthous ulcers, moniliasis, and Vincent's angina. The mouth lesions of lichen planus are punctate, striated, annular, papular, and usually accompanied by skin lesions. Lupus erythematosus rarely involves only the mucosa. The lesions are more inflammatory—congestion, edema, and erosions. The other diseases may be differentiated by acute symptoms, concomitants, and bacteriologic examinations.

Treatment.—It is customary to destroy small patches of leukoplakia with electrodesiccation or with the electric cautery. Many such lesions may be permanently cured with a single, intense application of the beta or gamma rays of radium. If, however, the lesion is stubborn, it is preferable to resort to the previously mentioned treatment rather than give repeated applications of radium. Large quiescent areas may be treated with radium, but it is preferable to treat them palliatively. Dental hygiene must be perfect. Tobacco is prohibited. Active areas should be excised or destroyed by the methods enumerated above. Treatment that is incapable of completely destroying the lesion should be avoided. If the patient has syphilis, modern antisyphilitic treatment is indicated. The mouths of patients with leukoplakia should be inspected every few months.

MISCELLANEOUS MOUTH CONDITIONS

Chronic gingivitis, pyorrhea alveolaris, apical abscess, sinuses, fistulas, erosions, ulcers, decayed teeth, etc., favor the development of cancer.

The dental profession deserves a great deal of credit, not only for superb mechanical ability, but because of the recognition that perfect oral hygiene is an exceedingly important health factor. The modern dentist urges his patients to have the teeth cleaned by a prophylactic dental nurse at least twice yearly, at which time the dentist inspects the entire mouth. Undergraduate and postgraduate instruction in diseases of the oral mucosa is given in many dental schools and dental societies. This knowledge, together with periodic dental examinations, should materially lessen cancer incidence. The dentist has the opportunity to detect many of the conditions that lead to cancer. Some of these must be treated by the dentist; others should be called to the attention of the family medical adviser.

leukoplakia, in the absence of ulcers, erosions, fissures, verrucous excrescences and vegetations, may be let alone and kept under observation. It is preferable, however, to perform a partial or complete vulvectomy followed by plastic repair. Such operation is essential when there is widespread leukoplakia, sclerosis and areas of erosion, ulceration and other danger signs.

LEUKOPLAKIA (LEUKOKERATOSIS)

It is the consensus of opinion that leukoplakia of the mouth may occur in both syphilitic and nonsyphilitic persons, and in smokers as well as non-smokers. Its etiology has not been definitely determined. Presumably it can be caused by syphilis and by local irritation. As a rule, antisyphilitic treatment has little if any effect on leukoplakia. When occurring in syphilitic persons, it is often associated with interstitial glossitis and smooth atrophy, a triad that is probably more dangerous than uncomplicated leukoplakia.

It is a fairly common affection in men; only about five per cent of the cases occur in women. While leukoplakia is dangerous, it is probable that many cases, perhaps the majority, never develop cancer.

FIG. 10.—Syphilitic interstitial glossitis, smooth atrophy, leukoplakia and erosions.

FIG. 11.—Syphilitic interstitial glossitis, smooth atrophy, leukoplakia and squamous-cell epithelioma.

Leukoplakia may occur in one or several very small patches on the tongue, lips, or mucous surfaces of the cheeks; or most of the buccal cavity may be involved. Small patches on the gums, under the tongue, on the roof of the mouth, behind the molars, etc., may escape careless examination.

The patches are white, usually marginated, irregular in size and shape, slightly thickened, and a trifle rough. The patient is often conscious of the affection, although subjective symptoms are not conspic-

all other scars and sclerosed tissue, cancer in lupus vulgaris, probably because of the dense fibrous tissue and sparse blood vessels and lymphatics, is likely to evolve slowly at first and to be of a comparatively low degree of malignancy.

The early stage of cancer in these cases is often mistaken for active lupus. Indeed, the clinical diagnosis may be difficult. Warty excrescences, a vegetating tumor, a pearly nodule, or a stubborn ulcer having an indurated margin, when occurring in a patch of lupus vulgaris or in scar tissue left by the disease, should be regarded with suspicion. In all such cases a biopsy should be performed. The treatment is that recommended for cancer—excision, plastic surgery, surgical diathermy and, in selected cases, roentgen rays and radium.

NEVI

Of the many forms of birth marks, the most dangerous is probably the almost flat, smooth, hairless, blue-black mole. Many of the melanomas have their origin in lesions of this type. While malignant

FIG. 13.—Blue-black mole.

change may be spontaneous, it is much more likely to follow traumatism, frequent irritation or injudicious treatment.

If such a lesion is quiescent and in a location where it will not be irritated, it may be let alone. But when there is the slightest evidence of activity, such as increase in size or thickness, ulceration, crusting, etc. (Hutchinson's malignant lentigo), or if there is possibility of repeated injury, the lesion should be radically destroyed. As a rule, it is preferable to remove malignant lentigo. This may be accomplished by a wide, deep excision or it may be radically destroyed with surgical diathermy. Radium and roentgen rays have produced excellent results in some cases.

There is a controversy relative to the advisability of removing an apparently quiescent blue-black mole. In the past, attempts at removal have been so often followed by recurrence and metastasis that many physicians prefer to do nothing. While it is true that many of these lesions never give rise to melanoma, very frequently indeed they do so.

LUPUS ERYTHEMATOSUS

Epithelioma of the squamous-cell type occasionally develops in the sclerotic tissue caused by the discoid variety of lupus erythematosus. The neoplastic evolution is at first slow, but as soon as normal tissue becomes involved the growth becomes fairly rapidly invasive. Like most epitheliomas that develop in scar tissue, the grade of malignancy is comparatively low. A persistent ulcer or erosion, a nodule or a vegetation, occurring in an area of lupus erythematosus or in sclerotic tissue resulting from a patch of lupus erythematosus, should be excised or destroyed with surgical diathermy. Roentgen rays or radium may be used, but the result is less certain.

It has been said that epithelioma, when apparently caused by lupus erythematosus, is really due to excessive roentgen-ray or radium treatment. Undoubtedly this is true in some cases, but epithelioma occurring in cases of lupus erythematosus has been reported in the absence of such treatment. Squamous-cell carcinoma occurs as a complication of lupus erythematosus in about 4 per cent of the cases.

FIG. 12.—Lupus erythematosus and squamous-cell epithelioma.

Gold and bismuth therapy have replaced, for the most part, all other therapeutic agents for this disease. Roentgen rays and radium are very seldom used for this purpose. Intravenous injection of gold sodium thiosulphate cures or controls many if not most of the cases. It will be interesting to compare lupus cancer statistics of the past with those compiled during the next twenty-five years.

LUPUS VULGARIS

It has been estimated that squamous-cell epithelioma develops in about 2 per cent of cases of lupus vulgaris. It is undoubtedly true that some of these cancers are due to the excessive use of roentgen rays or radium. On the other hand, cancer in lupus vulgaris lesions or scars was reported before the advent of roentgen rays and radium. As in

The blue-black mole should never be treated with caustics nor should it be squeezed. It should be let alone or completely removed.

The very common mole—pinhead- to split-pea-sized, elevated, smooth, more or less pigmented (various shades of brown) with or without hairs—is not considered dangerous unless subjected to repeated irritation. Large brown nevi, flat or elevated, with or without hair, in the absence of traumatism, are not very dangerous lesions. Cerebriform and other soft nevi are dangerous, as a rule, only when irritated or injudiciously treated. The same statement may be repeated

FIG. 15.—Pigmented hairy nevus.

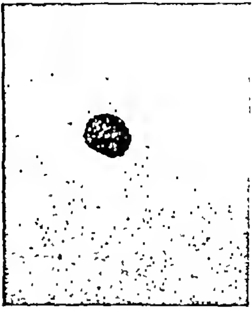

FIG. 16.—Papillomatous, verrucous nevus.

FIG. 17.—Mutiple dark-brown nevi.

When we are certain of the diagnosis, we prefer to remove this type of lesion by scalpel surgery provided, of course, that the location and size are suitable for such treatment. An incision is made through the skin at least one-quarter inch beyond the well-defined margin of the lesion. The incision then extends outward and downward to the muscle. When the tissue is removed, the lower portion will be wider than the upper portion. The excision is made in this way because occasionally the pigment-bearing cells may follow nerves and blood vessels downward and outward. The tissue should be examined immediately by frozen section or with a powerful magnifying lens, and, later, serial sections should be carefully examined under the microscope. In this way the diagnosis is established; also it is ascertained whether or not the lesion was completely removed. If not completely removed, a wider excision is made. The excision may be made either with a scalpel or with the cutting current. We prefer the former because surgical dia-

FIG. 14.—Common moles.

thermy in any form may interfere with a satisfactory microscopic examination.

As a rule, the blue-black mole is a small lesion (pinhead-sized or split-pea-sized). Occasionally, they are much larger—too large for excision. Occasionally, too, the situation precludes ordinary excision. In such instances the lesion may be let alone and kept under observation, or it may be removed by plastic surgery, depending on the judgment of the physician and the attitude of the patient and family.

The blue-black or gun-metal or slate-colored mole may be confused with dark-brown, much less dangerous nevi. It may be closely simulated, at times, by a tiny sebaceous cyst that happens to contain pigment or in which the refractive index is such as to produce a bluish-black appearance; also, very small hemorrhagic cysts may simulate malignant lentigo. The diagnosis, therefore, is not always easy.

Moles may be present at birth or they may appear months or years, sometimes many years, after birth.

be treated, as a means of cancer supervention, depends upon type, location, condition and the judgment of the physician. In selecting treatment for a given lesion, it is well to choose a method that is universally recognized as safe and proper. Many deaths have been caused by the incomplete destruction or the irritation of dangerous types of nevi with acids, solid carbon dioxide, electrodesiccation, electrolysis and other inadequate methods.

PAPILLOMA OF THE TONGUE

These lesions may be single or multiple. They are usually situated on the dorsal surface in the area of papillae. They are considered slightly dangerous because they are so likely to be repeatedly irritated or traumatized. It is advisable to destroy them with electrodesiccation. They may, of course, be excised either with scalpel or with the cutting current.

RADIODERMATITIS

This term includes all cutaneous injuries caused by roentgen rays or radium. A description of radiodermatitis is given in Chapter 4, Volume III. Severe acute radiodermatitis may result in an ulcer which never heals. Such an ulcer is dangerous because cancer is likely eventually to occur. Even when the ulcer heals, it leaves a scar that is far more dangerous than are ordinary scars. It is advisable to excise ulcers of this kind, by a plastic operation if necessary. By so doing, the patient is spared both time and severe pain; and, also, danger of subsequent cancer is removed.

A dangerous sequel of excessive roentgen-ray or radium treatment is the so-called roentgen-ray or radium skin. This consists of atrophy or sclerosis, telangiectasia and keratoses. These sequelae may result from an acute reaction with or without ulceration, or they may be the result of too many fractional treatments with or without a mild first degree reaction.

Permanent roentgen-ray and radium injuries should be occasionally inspected. In many instances the skin remains slightly atrophic and perhaps telangiectatic throughout the remainder of the patient's life, without the development of lesions that are dangerous. On the other hand, keratoses may develop. These keratoses may or may not lead to cancer. They frequently do so. They should at least be kept under observation. As a rule it is advisable to destroy them. This can be done with electrodesiccation. In our opinion, radium and roentgen rays are contraindicated for this purpose.

Skin that has been badly injured with roentgen rays or radium is likely to ulcerate when irritated or traumatized. It may ulcerate spontaneously. The ulcer may or may not heal. If it does not heal, it is very likely to end in cancer.

for verrucous nevi. Cancer rarely, if ever, develops on vascular nevi and lymphangiomas.

Nevi of various types are exceedingly common. Almost every person has at least one mole of the common variety. It is by no means necessary or advisable to destroy all moles, but their inspection should be a part of periodic health examinations. Whether or not a nevus should

FIG. 18.—Pigmented, keratotic nevus with malignant neoplasm.

FIG. 19.—Cerebelliform nevus.

be treated, as a means of cancer supervention, depends upon type, location, condition and the judgment of the physician. In selecting treatment for a given lesion, it is well to choose a method that is universally recognized as safe and proper. Many deaths have been caused by the incomplete destruction or the irritation of dangerous types of nevi with acids, solid carbon dioxide, electrodesiccation, electrolysis and other inadequate methods.

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FIG. 10.—Chronic radiodermatitis with squamous-cell epithelioma.

When skin of this type shows a tendency to ulcerate or to form frequent and numerous keratoses, it is advisable to remove it by excision or by a plastic operation. If this is impossible, the keratoses should be destroyed and the patient kept under observation.

SEBACEOUS CYSTS (STEATOMA; ATHEROMA; WEN)

Ricker and Schwalb [11] report 43 cases of sebaceous cyst in which cancer developed in the cyst wall. Caylor reported 12 similar cases.[12] When cancer occurs it is usually a squamous-cell epithelioma although basal-cell epitheliomas have been reported. Malignant change occurs more often when the cyst first undergoes ulceration. Sebaceous cysts are exceedingly common, and they are easily removed by excision.

FIG. 21.—Sebaceous cyst.

FIG. 22.—Same as Fig. 21. After excision.

SYPHILIS

Cancer is a frequent complication of interstitial glossitis, and smooth atrophy of the tongue of late syphilis. The same may be said of syphilitic leukoplakia. The management of leukoplakia has been already discussed. Little can be done for the other two conditions. The patient should be kept under observation and, of course, he should receive antisyphilitic therapy. Early cancer of the tongue in these cases is frequently mistaken for gumma or other manifestation of syphilis, a mistake that can be avoided by microscopic examination. Many dermatologists believe that the administration of arsenic increases the danger of cancer in cases of syphilitic glossitis, smooth atrophy and leukoplakia. We doubt the contention.

Cancer may occur in scars left after the healing of destructive lesions of syphilis. Also, cancer has been reported in cases of gumma; but most of these reports were of tongue cases and it is probable that they were cases of squamous-cell epithelioma occurring in interstitial glossitis rather than in a gumma.

ULCERS AND FISTULAS

A few cases of squamous-cell epithelioma developing in long-standing varicose ulcers of the leg have been reported. The incidence of malignancy is very small when one considers the frequency with which the so-called varicose ulcer occurs. In the literature one finds frequent reports of metastatic cancer occurring in ulcers of various types: decubitus ulcer, pellagrous ulcers, ulcerations in acrodermatitis chronica atrophicans and scleroderma, third degree burns and, of course, ulcers caused by roentgen rays and radium.

Cancer following long-standing fistulas and sinuses caused by disease or injuries has been frequently reported. We recently saw a case of osteomyelitis, the result of an accident, which had failed to respond to the usual treatment. A sinus formed, followed by squamous-cell epithelioma of relatively low-grade malignancy, necessitating amputation of the leg.

Fig. 13.—Von Recklinghausen's disease.

VON RECKLINGHAUSEN'S DISEASE (MULTIPLE NEUROFIBROMATOSIS)

Hosol[11] reports 65 cases of this affection in which sarcoma developed. He states that sarcoma develops in 13 per cent of the cases of multiple neurofibromatosis. This figure seems high to us. We have seen many cases of multiple neurofibromatosis but we have not seen a single case of associated sarcoma.

It may be that of all cases of von Recklinghausen's disease in which tumors are excised, 13 per cent become sarcomatous after surgical interference. Hosol reports one case in which sarcoma developed one year after the excision of a tumor. It has been observed by others that removal of a tumor by surgical excision may result in sarcoma. These sarcomas are not very malignant and seldom undergo metastasis, yet the prognosis is poor. Recurrence after repeated operations is the rule. If death does not result from metastasis, it follows operative and postoperative complications.

The course of von Recklinghausen's disease is not modified by treatment of any kind. It would seem that surgical intervention were contraindicated.

XERODERMA PIGMENTOSUM

This rather rare affection is thought to be due to congenital lack of resistance to sunlight. It begins early in life, there is a predilection for the exposed parts and it is incurable. The affection simulates chronic radiodermatitis, sailors' or farmers' skin and senile skin. Pigmentation and atrophy are first noted. This is followed by keratoses and epithelioma, usually of the basal-cell type.

Very little can be done for these unfortunate children. Only those with a mild example of the affection reach adult life. These patients should be thoroughly protected from even indirect sunlight. Preferably they should be exposed only to artificial light which contains few if any actinic rays. When in the open they should wear gloves, sleeves, dark-colored veils, etc. Keratoses, epitheliomas and ulcerations should be destroyed as soon as detected. This can be done, as a rule, with electrodesiccation.

MISCELLANEOUS CONDITIONS

The skin of elderly persons may show atrophy, permanent freckles (lentigo) and keratoses. The condition is usually more pronounced on the face and hands, although it may occur on the trunk and, in fact, on almost any part of the body. It may occur in those who have never been exposed very much to actinic rays. It resembles sailors' skin and is known, simply, as senile skin. Occasionally it begins between the ages of 35 and 50, without apparent reason. This has been called presenile skin. The keratoses occurring in such skin have the same potentialities as senile keratoses and are treated in the same manner.

Fig. 14.—Xeroderma pigmentosum.

Permanent freckles, with predilection for face, shoulders and backs of hands, may be a manifestation of senile skin or of farmers' skin. They occur mostly after the age of 60, although they are fairly common at 40 and 50. Occasionally one of these pigmented macules may change to a keratosis and the latter may give rise to cancer. However,

FIG. 25.—Neurofibroma.

FIG. 26.—Same as Fig. 25. After excision.

FIG. 27.—Neurofibroma.

FIG. 28.—Same as Fig. 27. After excision.

this happens so seldom, that it is not necessary to treat a permanent freckle unless a keratosis develops.

Sebaceous adenomas are pinhead-sized, umbilicated papules seen most frequently on the forehead of middle-aged and old persons. The color is about that of normal skin. We think that we have seen epithelioma develop in these lesions. The condition is to be differentiated from adenoma sebaceum.

FIG. 29.—Fibroma.

FIG. 30.—Same as Fig. 29. After excision —four days after operation.

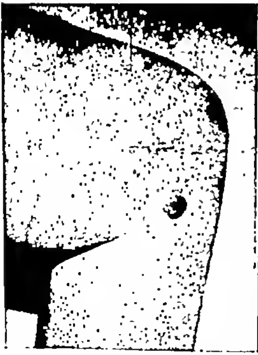

FIG. 31.—Fibroxanthoma (histiocytoma).

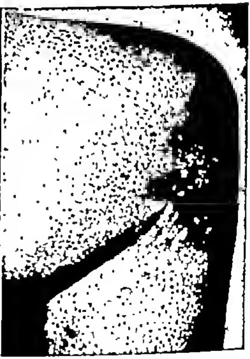

FIG. 32.—Same as Fig. 31. After excision.

Lesions falling in the category of multiple benign cystic epithelioma —tricho-epithelioma; syringocystoma, etc.—occasionally change to a malignant neoplasm, usually basal-cell epithelioma. The same is true for certain endotheliomas. In fact, there are a large number of benign lesions such as fibroma, neurofibroma, fibroxanthoma, etc., that may, under certain conditions, give rise to cancer. However, none of these lesions is considered dangerous unless repeatedly irritated over a long period of time. Paraffinoma has been known to change to cancer. Cancer has been reported in cases of Darier's disease (keratosis follicularis). Acanthosis nigricans in adults usually indicates cancer of the viscera.

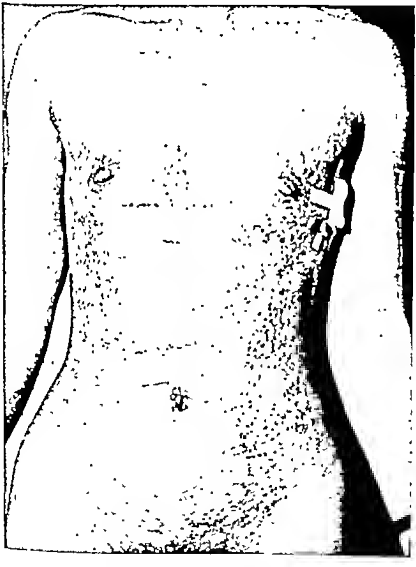

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Fig 33.—Syringocystoma.

Cutaneous Malignant Neoplasms

General Therapeutic Considerations.—In the past, dermatologists and others treated cutaneous cancer with the method with which they were most familiar, regardless of type, size, depth and location of the lesion. Thus the surgeon always employed the scalpel, the roentgenologist depended solely on roentgen rays, the radium specialist used only radium, the diathermy enthusiast insisted on the use of surgical diathermy and so on. The same statement is true today but to a lesser degree. Statistics show that excellent results may be obtained in properly selected cases with any of these methods when expertly applied. The results are not so good in unselected material. There is no best method for the treatment of unselected cases of cutaneous malignant neoplasms. Any one method or a combination of methods may be the best procedure for an individual case. The physician who has had extensive experience with all the recognized methods of treating malignant neoplasms of the skin and orificial mucous membranes, and who is thoroughly acquainted with the clinical and histologic characteristics of such neoplasms and the conditions that may cause them, is in a position to employ discriminating judgment and to obtain the best results. Undoubtedly statistics will improve when every physician who attempts the management of cutaneous cancer possesses this comprehensive ability. Here, too, there is need for more and better postgraduate instruction.

The recognized methods of treating cutaneous malignant neoplasms are scalpel surgery, surgical diathermy, roentgen rays and radium.

Roentgen Rays.—Roentgen rays are satisfactory for many basal-cell epitheliomas. Small superficial growths may be treated with unfiltered radiation. Moderate or heavy filtration is preferable for thick or deep-seated lesions. It seems that approximately the same results are obtained by large doses administered at intervals of two or more months or by smaller doses so spaced that an intense effect is obtained in a week or two (fractionation). It should be emphasized that when a lesion fails to respond favorably to treatment that should be adequate, the treatment should be discontinued. When containing squamous cells, when involving cartilage and other subcutaneous structures, and when composed of hard nodules, basal-cell epitheliomas are likely to resist roentgen rays. Many basal-cell epitheliomas will disappear with hardly a trace as a result of roentgen-ray therapy; but the cosmetic result is occasionally disappointing because of atrophy and telangiectasia subsequent to radiation, and scarring caused by the disease.

Roentgen rays produced by very high voltage, and heavily filtered, are very useful for selected cases of squamous-cell epithelioma and, also, for inoperable cases.

Radium.—In general, what has been said relative to roentgen rays may be repeated for radium. Radium is the more preferable of the two agents for unselected cases of cutaneous squamous-cell epithelioma. It can be used in locations that are inaccessible to roentgen rays. There is better opportunity for cross-fire, radon implants may be used, there is greater penetration, and so on. For selected cases, assuming proper facilities and expertness, the results are probably approximately the same with either agent. It may be interjected that the facilities and skill required for the modern roentgen-ray and radium treatment of squamous-cell epithelioma, even of the skin and orificial mucous membranes, are so exacting that they are found in comparatively few medical institutions and private offices. In the near future it may be possible to employ, in practical work, roentgen rays produced by a million or more volts and filtered with heavy metal of considerable thickness. Such radiation will compare favorably in penetrability with heavily filtered gamma rays.

Surgical Diathermy.—The production within the tissue, by means of a high-frequency current, of an amount of heat sufficient for destructive purposes, is known as surgical diathermy. Three forms of surgical diathermy are universally employed. They have been designated electrocoagulation, cutting current and electrodesiccation. The first two depend on current obtained from various parts of the primary winding of the high-frequency transformer. Either of these currents may be bipolar or monopolar, damped or undamped. The current for electrodesiccation is monopolar and it is obtained from the secondary winding of the high-frequency transformer.

With electrodesiccation it is possible, by surface sparking, to dehydrate or mummify a pinhead-sized superficial area, or a fairly extensive superficial lesion. By multiple insertions of the active needle electrode, one may destroy rather large, thick lesions. The method is employed mostly for the destruction of small, superficial benign growths, potentially dangerous lesions such as leukoplakia, keratoses, etc., and small superficial epitheliomas of the basal-cell type. It is being abused by many physicians who employ it mistakingly for electrocoagulation and who use it without any form of anesthesia.

The current for electrodesiccation has an exceedingly high voltage and a comparatively low milliamperage. That for electrocoagulation has a lower voltage but a higher milliamperage. The cutting current has still lower voltage and higher milliamperage.

The electrocoagulating current, when used as a surface spark, dehydrates to some extent, but the principal effect is that of rather widespread coagulation of tissue, especially when the active needle electrode is inserted into the tissue as is usually done. The gross change may be no more than a blanching or whitening of the tissue which later sloughs. Electrocoagulation seals the blood vessels and lymphatic vessels. It is used mostly for the destruction of malignant neoplasms.

It is customary first to establish a line of deep coagulation beyond the periphery of the lesion; the entire lesion is then coagulated and removed with the cutting current, scalpel or curet, after which the wound may be electrodesiccated or superficially electrocoagulated. Coagulation can be performed with the bipolar current, using either a single or bipolar active needle electrode or with monopolar current from the same source.

The cutting current cuts like a knife and causes enough coagulation to seal the small blood vessels and lymphatic channels. Theoretically at least, there is less chance of metastasis during the application of surgical diathermy than with the scalpel or curet. Excision with the cutting current is comparatively bloodless. It is possible to obtain primary union, especially if the edges of the wound are freshened with the scalpel or scissors.

Surgical diathermy can be employed satisfactorily when scalpel surgery would be difficult or impossible. When using high-frequency currents for destructive purposes, one is likely to think in terms of physical therapy rather than in terms of surgery, which may lead to careless technic from a surgical standpoint. Surgical diathermy is surgery, and to it should be applied the principles of general surgery. Good results may be obtained by the use of the actual cautery.

Sherwell Method.—There is another therapeutic method occasionally used by dermatologists for selected cases of cutaneous cancer which may be placed among the conventional methods. We refer to the Sherwell method. It consists of the removal of as much of the neoplastic tissue as is possible with curet, scalpel, scissors, and high-frequency current, after which acid nitrate of mercury is applied for at least five minutes. The wound is then covered with a thick layer of bicarbonate of soda, over which is placed a dry dressing. Instead of acid nitrate of mercury, Morrow and Taussig[14] employ chemically pure red crystals of chromic acid, while Angle[15] and others use a saturated aqueous solution of zinc chloride.

Contraindicated Treatment.—Some physicians advocate the use of physical therapy agents for the treatment of cutaneous cancer that have been given a fair trial by dermatologists who find that they are unsuitable for the purpose. Among these agents are solid carbon dioxide, electrolysis and ultraviolet radiation.

Biopsies.—When possible it is advisable to make a microscopic examination before instituting treatment. This is the only way in which a definite diagnosis can be made. Also it is the only way in which the grade of malignancy can be accurately determined. When the lesion is small and suitably situated, the biopsy might well consist of complete excision with the scalpel. Examination of serial sections provides invaluable information relative to invasiveness, metastasis, and complete or incomplete removal, in addition to determining

the grade of malignancy based on cytology, tissue reaction and other features.

Many physicians aver that a biopsy made with scalpel or biopsy punch is dangerous; that such procedure favors dissemination of the malignant cells. They prefer to remove the piece of tissue with the cutting current. It is now the consensus of opinion of those who have had extensive experience that a biopsy made with scalpel or biopsy punch is not dangerous when properly performed. The instruments must be sharp and the lesion must not be squeezed, massaged or unduly manipulated. The cutting current, unless the excision is very wide, is likely to interfere seriously with the microscopic study because of coagulation of cells.

Classification of Cutaneous Malignant Neoplasms

There is, as yet, no universally accepted classification for malignant neoplasms of the skin and orificial mucous membranes. In this chapter the following conditions will be discussed:

1. Basal-cell epithelioma
2. Basal-squamous-cell epithelioma
3. Squamous-cell epithelioma
4. Transitional-cell epidermoid carcinoma
5. Paget's disease
6. Bowen's disease
7. Melanomas
8. Sarcomas

BASAL-CELL EPITHELIOMA

The term *basal-cell epithelioma* includes names such as Jacob's ulcer, cancroid, rodent ulcer and benign skin carcinoma, all of which are now obsolete.

Krompecher,[14] in 1902, was the first investigator to separate basal-cell epithelioma from other epithelial cancers. His work has done a great deal to clarify our knowledge of the malignant cutaneous new growths.

The basal-cell epithelioma is relatively benign and causes death only by hemorrhage, involvement of important parts such as the articulations and orbit, or when complicated by septic infection. The affection rarely involves the mucous membranes primarily, although secondary involvement of these structures is common. In other words, basal-cell epithelioma practically always begins in the skin. Metastasis is rare in basal-cell epithelioma of pure type. The prognosis both for life and for permanent cure is excellent but must be guarded when dealing with deep lesions. It is not necessary to treat every basal-cell epithelioma. They should be treated when occurring in patients who are under 60 years of age. Small, superficial lesions in old and very old persons, especially when multiple, may be let alone and kept

under observation. Evolution is likely to be so slow that the lesion will not become serious during the patient's remaining years. Ulcerated lesions, deep lesions, and lesions that have involved or threaten to involve important structures should, of course, be destroyed, regardless of age. Lesions that are in skin that is thin—nose, forehead, eyelids, ears, etc.—should be watched carefully or destroyed, otherwise underlying important structures may become involved.

The neoplasm originates from the basal-cell layer of the epidermis —most likely from cells that were predestined to form cutaneous appendages. It also arises from the basal-cell layer of the epithelium of the cutaneous appendages—sebaceous glands and ducts, and sweat glands and ducts, especially from the sebaceous glands.

FIG. 34.—Flat type of basal-cell epithelioma.

Under the microscope the lesion consists of basal cells that fail to develop into squamous or prickle cells; therefore, there is no keratinization; no whorls. As a rule, there is considerable tissue reaction around the neoplasm.

Clinically, the affection varies considerably in appearance due both to clinical type and stage of evolution. Usually the evolution is exceedingly slow—very slow extension over a period of many months; usually many years. The affection is most common during or after middle life. It is quite common in the third and fourth decades and occurs occasionally during late adolescence. The sites of predilection are the face and trunk, although it may occur on almost any part of the body surface. Males are affected more frequently than are females.

Hazen [5] classifies basal-cell epithelioma into seven clinical types:

1. Flat type
2. Nodular
3. Ulcer with rolled edge
4. Lesion resembling a depressed scar
5. Morphea-like epithelioma
6. Fungating tumors
7. Deep type

Fig. 35.—Multiple basal-cell epithelioma of the flat type—multiple epitheliomatosis cutis.

Flat Type.—The flat type consists usually of a brown-colored macule with a delicate rolled edge. The edge is slightly elevated, narrow and somewhat translucent. In color and appearance the edge

suggests mother-of-pearl. They range in size from the head of a pin to split-pea, silver quarter, fifty-cent piece, silver dollar and larger. The bulk of the lesion may be flat (macular), slightly elevated, smooth, scaly or crusted. It may be studded with pearly nodules and it may ulcerate. As a rule the lesion is dry, but it may be exudative. The lesion spreads very slowly by peripheral extension. The center may cicatrize. The lesions very often are multiple; frequently there are many lesions.

This type of basal-cell epithelioma is also known as multiple epitheliomatosis cutis, and serpiginous cicatrizing epithelioma. At times it resembles the so-called Bowen's precancerous dermatosis, extramammary Paget's disease, keratosis seborrheica, psoriasis, syphilis, tuberculosis, etc. As a rule the clinical diagnosis is easily made. Occasionally a biopsy is necessary. If so, it is essential that tissue from the margin be examined rather than tissue from the center of the lesion. The flat type is very superficial and usually remains so for many years. Eventually it may become nodular or ulcerative and may invade the subcutaneous tissues.

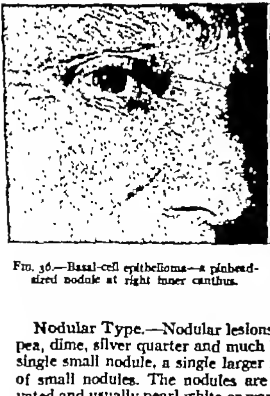

FIG. 36.—Basal-cell epithelioma—a pinhead-sized nodule at right inner canthus.

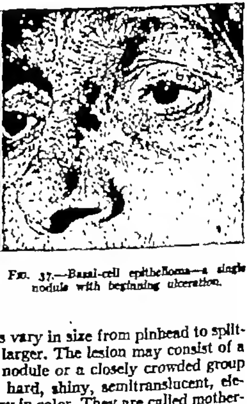

FIG. 37.—Basal-cell epithelioma—a single nodule with beginning ulceration.

Nodular Type.—Nodular lesions vary in size from pinhead to split-pea, dime, silver quarter and much larger. The lesion may consist of a single small nodule, a single larger nodule or a closely crowded group of small nodules. The nodules are hard, shiny, semitranslucent, elevated and usually pearl-white or waxy in color. They are called mother-of-pearl or [illegible]xy nodules. There is usually some telangiectasia. The lesion ma[illegible]nain nodular for years or it may undergo ulceration. The nod[illegible] type is at times confused with nodular syphilis, lupus vulgaris and other affections. The clinical diagnosis is easily made as a

FIG. 38.—Basal-cell epithelioma. Lesion is composed of numerous closely crowded nodules.

FIG. 39.—Basal-cell epithelioma composed of coalesced nodules—beginning ulceration.

FIG. 40.—Basal-cell epithelioma composed of a rim of coalesced nodules and a cicatrized center. There is some ulceration.

rule. Lesions having an unusual macroscopic appearance give a typical microscopic picture.

Depressed Scar Type.—This is an uncommon type. It consists of a slightly depressed scar or a slightly depressed area of atrophy or sclerosis. It may represent what was formerly known as the serpiginous

cicatrizing type. There may or may not be ulceration, nodules and a delicate rolled edge. Often the clinical diagnosis is difficult. Even the microscopic diagnosis may be difficult unless the area for biopsy is selected with care.

Morphea-Like Type.—In this variety the lesions are flat, somewhat round in contour and sharply marginated. The area may be atrophic and slightly depressed, or slightly thickened and elevated. The color is yellowish or pinkish-yellow and there is usually some telangiectasia. Sooner or later ulceration occurs. It is an uncommon type of basal-cell epithelioma.

Fungating Type.—In this variety the lesion, which may be of almost any size, usually is an ulcer covered with a vegetating or fungoid mass, and associated with a foul-smelling exudate. Wary

Fig. 41.—Deep type of basal-cell epithelioma.

nodules may appear at the periphery or in various parts of the lesion. Occasionally, this type may be papillomatous, giving rise to a cauliflower-like tumor; or it may be verrucous. It may be mistaken for squamous-cell epithelioma, tuberculosis, syphilis, blastomycosis, bromoderma, iododerma and other affections.

Deep Type.—This form may originate from any of the other types or it may develop independently. In the latter case, when first detected, it consists of a small nodule deep in the skin or in the subcutaneous tissue. The surface is usually red, perhaps atrophic and telangiectatic. The nodule increases in size, spreading laterally and downward, involving the deeper tissues. Eventually there is ulceration surrounded

FIG. 41.—Basal-cell epithelioma of skin over shoulder.

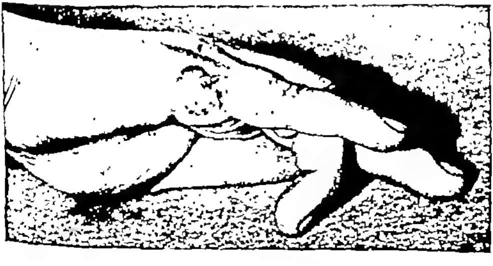

FIG. 43.—Basal-cell epithelioma of finger.

by induration and extensive destruction of tissue. When developing from other types, a deep indurated ulcer is produced which gradually destroys important tissue. It is the deep ulcerating type that used to be called rodent ulcer. It directly and indirectly destroys subcutaneous tissue, cartilage, periosteum, the eye, and other important structures. When developing independently as a deep nodule it is often impossible to establish a diagnosis without the aid of the microscope.

Treatment.—Selection of method for the treatment of basal-cell epithelioma is based on a number of factors such as: circumference, thickness and depth of lesion, type (superficial, deep, nodular, ulcerating, morphea-like, etc.), previous treatment, primary or recurrent growth, location and tissue involved, and age and sex of the patient; and, also, the desires of the patient.

Scalpel Surgery.—A lesion that does not involve cartilage or periosteum, that is suitably situated and that is not too large, may be

Fig. 44.—Basal-cell epithelioma of chin.

Fig. 45.—Same as Fig. 44. After scalpel excision.

excised with the scalpel and primary union obtained. If the skin heals normally and the surgical technic is proper, the ultimate scar is less conspicuous than that following electrocoagulation or electrodesiccation, unless the lesion is exceedingly superficial, in which case methods other than surgical excision are indicated. Excision with the scalpel has, of course, limitations, but it has the advantage of permitting serial sections of the entire lesion. In this way one confirms or refutes the diagnosis and ascertains whether or not the entire neoplasm has been removed. If there is doubt about complete removal, a larger excision may be made or roentgen rays or radium may be applied. Scalpel

surgery is especially efficacious for the deep type consisting of a small nodule in the skin or subcutaneous tissue.

There are many cases in which an extensive neoplasm has involved important organs such as the nose, ear, eye, etc. The majority of such lesions have been previously treated with roentgen rays or radium or surgical diathermy or with all three methods. In such instances the best results are usually obtained by removing or destroying all neoplastic tissue by means of conventional surgery or with surgical diathermy, after which the deformity is corrected, as much as possible, with plastic surgery.

Caustics.—Superficial lesions, such as the flat type, may be cured by first thoroughly curetting, under local anesthesia, then applying

Fig. 46.—Deep type of basal-cell epithelioma of nose.

Fig. 47.—Same as Fig. 46. After surgical diathermy.

zinc chloride, acid nitrate of mercury or, when very superficial, even trichloracetic acid. The Sherwell method is used, as a rule, for deep lesions that have involved important structures and in which other methods have failed. The results are excellent when the cases are properly selected.

Surgical Diathermy.—This is a popular method among dermatologists. Very superficial lesions are dehydrated by electrodesiccation, removed with the curet and the wound is again electrodesiccated. It is important to extend the destruction of tissue for at least a quarter of

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Roentgen rays and radium are very likely to fail when cartilage and periosteum are involved.

The majority of operators favor the administration of large doses at intervals of one or two months—from one to six or eight times the erythema dose, depending on size of lesion, age of patient, location of lesion, thickness of filter, etc. Unfiltered radiation is used for superficial lesions, while moderately heavy and heavy filtration are employed for thick, deep-seated lesions.

Some operators favor dividing the total dose for one month, administering a fraction of the total dose every few days. This has been referred to as the modified Coutard [14a] technic. It is claimed that by so

Fig. 48.—Ulcerated nodular basal-cell epithelioma of left inner canthus.

Fig. 49.—Same as Fig. 48. After two intensive doses of roentgen rays.

doing a larger total dose can be given without undue reaction, which is probably true, and that there is a better chance of catching cells in the act of dividing, at which time they are more "radiosensitive." However, there is no convincing evidence that this method gives results that are superior to large doses given once every month or two. When using a copper filter with very high voltage roentgen rays, it may be necessary, for technical reasons, to give a fraction of the total dose every day or two until the treatment is completed.

When a basal-cell epithelioma fails to disappear as a result of two or three large doses of roentgen rays, or when it recurs more than once following roentgen-ray treatment, it is advisable to resort to some other therapeutic method. Normal skin, except that in the immediate vicinity of the lesion, should be adequately protected. Roentgen rays should never be applied to the eyelids without proper protection for the eyeball. The eye may be desensitized with a few drops of one or two per cent holocaine solution. Then a brass-aluminum or lead glass eye shield is sterilized, dipped in sterile olive oil and slipped under the eyelids.

Overdosage should be avoided. A third-degree roentgen-ray reaction

an inch beyond the macroscopic edge of the lesion. It is equally important to carry the destruction downward into normal tissue. A recurrence at the edge of a scar is soon detected. A recurrence or continuation under a scar is likely to do considerable damage before it is recognized. Many dermatologists also administer a single dose of unfiltered roentgen rays consisting of from one to three or four skin units—from about 300 to 1200 r, or the equivalent dose of gamma rays of radium.

Lesions that are large, thick and deep are usually thoroughly electrocoagulated. The coagulated tissue is removed and the wound is again electrocoagulated. This may be accomplished under general or local anesthesia. Many physicians prefer to finish the treatment with a hyperintensive dose of filtered roentgen rays—from two to eight skin units (140 Kv., 3 mm. Al, 1100 to 4400 r), depending on size of lesion and age of patient, or filtered gamma rays of radium in equivalent dosage.

A lesion may, of course, be excised with the cutting current, followed either by primary union or healing by granulation tissue.

Scars following the destruction or removal of a basal-cell epithelioma with surgical diathermy are likely to be disfiguring, especially when the lesion occupies the entire thickness of the derma or has invaded tissue under the skin. Very often they are hyperplastic or keloidal. Very superficial lesions may be destroyed with very little scarring.

There is no way of knowing, when coagulation is used, whether or not all the neoplastic cells have been destroyed. On a number of occasions we have excised a scar left by such treatment and have found neoplastic cells in the scar tissue. It is possible that some malignant cells escape destruction in many cases that are permanently cured, but because they are entirely sorrounded by dense scar tissue, they either remain dormant or perhaps eventually die. In any event, it is possible to obtain at least 85 per cent permanent cures in unselected cases of basal-cell epithelioma with this method. Many superficial lesions, especially the early ones, may be destroyed by the actual cautery.

Roentgen Rays.—It is possible to cure at least 85 per cent of unselected basal-cell epitheliomas with roentgen rays. The percentage of cures in selected cases is, of course, higher. Hazen and Whitmore [17] reported a series of 200 unselected cases with 86 per cent permanent cures. They obtained 93 per cent cures in selected cases. MacKee,[18] in a series of 400 cases, obtained 87 per cent cures in unselected cases and 91 per cent in selected cases. Some authors report a much higher percentage of cures, 100 per cent, in fact, while others obtained only 60 or 70 per cent. It is doubtful if it is possible to obtain 100 per cent cures in a large series of unselected cases of basal-cell epithelioma with either roentgen rays or radium. It may be possible to approach this figure with thoroughly modern roentgen-ray or radium treatment, when the cases are selected and when in each case the diagnosis is made microscopically.

BASAL-SQUAMOUS-CELL EPITHELIOMA

It has long been known that 12 or 15 per cent of basal-cell epitheliomas contain squamous or prickle cells. Curiously, it is just about this percentage of cases that have proved unusually stubborn. Hamilton Montgomery[19] found this type of epithelioma in 12.6 per cent of a series of 119 cases of skin carcinoma, most of which, clinically, were of the basal-cell type. It is difficult, if not impossible, clinically to differentiate between a pure basal-cell epithelioma and one of the basal-squamous-cell type, especially in the early stages of evolution. Histologically, one portion of a section may show only basal cells while another portion may show the characteristics of a squamous-cell growth. Quoting Montgomery: "They represent a metamorphosis of basal-cell epithelioma to squamous-cell epithelioma and are not degenerate forms of the latter." It is necessary to study carefully the entire section, sometimes several or many sections, otherwise the true nature of the lesion may be overlooked. This type of epithelioma begins, looks and it may behave like a pure basal-cell epithelioma, but often it behaves like a squamous-cell growth. That is, it may prove recalcitrant and it may cause death. In the past there have been a few reports of metastasis occurring in cases of basal-cell epithelioma. It is not improbable that these lesions were of the basal-squamous-cell type.

The treatment should be the same as that recommended for squamous-cell epithelioma. While, as a rule, the degree of malignancy is not high, yet the prognosis should be guarded.

FIG. 50.—Basal-squamous-cell epithelioma.

FIG. 51.—Same as Fig. 50. After removal with cutting current followed by roentgen-ray treatment.

SQUAMOUS-CELL EPITHELIOMA

The term *squamous-cell epithelioma* (prickle-cell epithelioma) signifies a malignant growth originating from cells of the epidermis above

is likely to be more troublesome and more serious than is the usual basal-cell epithelioma. Very often a basal-cell epithelioma, when treated with roentgen rays, will disappear with only a slight cutaneous defect. Not infrequently, however, there is a scar, atrophy or telangiectasia. In other words, while the chance for a good cosmetic result is excellent, the result in this respect may not be satisfactory. Of course, the cosmetic result depends on a number of factors—size of dose, location, age, sex, idiosyncrasy, character of the lesion, etc.

Radium.—In general, what has been stated about roentgen rays in the preceding section pertains, also, to radium. Assuming technical skill, proper equipment, and judgment in selection of cases, future statistics will be probably approximately the same for both agents.

In certain locations better results can be often obtained with radium than with roentgen rays—lesions on the edge of the eyelid, lesions including the nasal or buccal mucous membranes, a lesion in the external auditory canal, etc. A tubular applicator may be placed in the external auditory canal. A cast or mold of the mouth can be made in which screened radium or radon is embedded in proper position. The mold is held in the mouth during treatment.

Very superficial lesions may be treated with a half-strength radium element applicator screened with 0.1 mm. Al. The applicator is held in contact with the lesion for one or two hours. Such treatment gives an intense beta-ray effect. Deeper lesions should be treated with gamma rays. The same applicator is screened with 2 mm. of brass and 1 mm. Al. This is held in contact with the lesion for from eight to twenty-four hours. If so desired the time factor may be divided so that an application of from two to four hours is given daily.

Lesions that are very deep, thick or indurated are usually treated with radon. Radon tubes may be screened with 0.5 mm. Ag, 1 mm. brass and 1 mm. Al. Such a tube containing 100 mc. radon is placed at a distance of 2 cm. from the lesion and held in place with adhesive for a period of from 2 to 6 hours. Such treatment may be repeated in two weeks or a month. In selected cases implants or seeds each containing 1 to 2 mc. of radon are embedded 1 cm. apart throughout the tumor mass. These seeds are not removable. Removable platinum radium needles may be used. Needles, each containing 1 or 2 mg. radium, are placed 1 cm. apart in the mass. These are sutured in place for from 96 to 144 hours.

Grenz Rays.—The very long roentgen-ray wavelengths known as grenz rays have been used to some extent for the treatment of basal-cell epithelioma. The number of cases treated is too small and the length of time since treatment is too short for a fair evaluation of the method. It is probable that they will be of little real value for this purpose. They have been used with apparent success for the treatment of very superficial basal-cell epithelioma, epecially of the upper eyelids.

the basal-cell layer, or from similar cells in the epithelial layer of the cutaneous appendages. Under the microscope, in addition to finger-like down-growths of the epidermis, it is seen that some of the cells become more or less keratinized, thus forming the characteristic whorls or pearl-like bodies. Tissue reaction is not so marked as in basal-cell epithelioma.

Occurrence.—Squamous-cell epithelioma occurs about half as frequently as does basal-cell epithelioma. They develop most frequently in the mucous membranes of the lip and mouth. They are seen less frequently on the penis, vulva, eyelids and nose. When occurring in

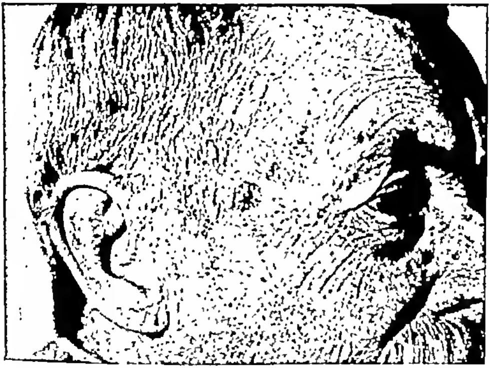

Fig. 54.—Squamous-cell epithelioma of rim of right ear. Note senile keratoses on face.

the skin, the most common locations are the scalp, dorsal surfaces of the hands, and the ear. Probably in the majority of cases the malignant growth is preceded by one of the so-called precancerous conditions, especially senile keratosis and leukoplakia. The majority of patients are over 35 years of age. Carcinoma of the tongue is relatively uncommon in women. Statistics show that the affection is about three times more common in males than in females.

Clinical Characteristics.—The lesion may begin as an ulcer or as a nodule. Ulcers are usually indurated. Nodules continue to grow in size to form a tumor which may be hard or soft, and which as a rule

Fig. 52.—Basal-squamous-cell epithelioma. Originally diagnosed as tuberculosis and ring finger amputated. Epithelioma is present in the scar. There is an epithelioma on the flexor surface of forearm. Epithelioma developed in the axillary glands, and the arm was amputated. Case reported by Henry D. Niles (Metastasis of a basal cell epithelioma, Am. J. Cancer, Vol. 15, July, 1931).

Fig. 53.—Same as Fig. 52. After amputation.

and perhaps even a day may mean the difference between life and death.

As a rule, metastasis occurs in the regional lymphatics, but not infrequently the first evidence of metastasis consists of a tumor of the bones or some organ.

Occasionally, carcinoma attacks the skin secondarily from a focus in some other organ. An example of such secondary invasion is cancer *en cuirasse.*

Prognosis.—Squamous-cell epithelioma is a very serious affection and even in favorable cases the prognosis must be guarded. It is of the utmost importance to detect the lesion, establish a microscopic diagnosis and completely remove or destroy the lesion while it is still local. Of course, there is no way of knowing how early metastasis

Fig. 56.—Squamous-cell epithelioma of left ring finger.

may occur, but when the lesion, as revealed by the microscope, shows an intact basal-cell lining, no finger-like processes and no invasiveness, it is probable that metastasis has not yet occurred.

Based on cytology, squamous-cell epitheliomas are of four recognized grades of malignancy. Clinical dermatologists recognize several grades of malignancy based on clinical features. As we have seen, when the lesion develops in sclerotic tissue, as in lupus, interstitial glossitis, scars, "x-ray skin" and in some keratoses and some cases of leukoplakia and kraurosis, evolution is likely to be slow and metastasis delayed. Epithelioma developing in an apparently normal tongue is apt to be rapidly invasive. On the whole, the evolution of squamous-cell epithelioma of the apparently normal skin is not particularly rapid, but occasionally a lesion will appear suddenly in apparently normal skin or membrane, invasion of neighboring tissue being rapid and metastasis occurring very early.

is opaque rather than semitranslucent as in basal-cell epithelioma. Nodules and tumors often ulcerate. Not infrequently the lesion is verrucous, vegetating or papillomatous. As a rule there is but a single lesion. Occasionally there are several. When occurring in scar tissue, or similar tissue, and when of a comparatively low grade of malignancy, the growth may be slow and metastasis delayed. As a rule, however, evolution is rapid and metastasis occurs early.

The lesion is always sharply defined and usually indurated. The disease invades practically all tissues—connective tissue, cartilage, periosteum, bone, viscera, lymphatic system, etc.

FIG. 55.—Same as Fig. 54. After removal with cutting current.

The affection must be differentiated from syphilis, tuberculosis, basal-cell epithelioma and a number of other conditions. A dermatologist can usually make a fairly accurate clinical differentiation, but the proper way to avoid diagnostic error is by microscopic examination.

It often happens in cases of tongue cancer in a syphilitic patient, that the physician will waste valuable time with the so-called therapeutic test; that is, he will administer intensive antisyphilitic treatment over a period of several months. In all such cases it is advisable to make a microscopic examination at once. It is important to keep in mind that squamous-cell epithelioma is so serious that a month, a week

these cells would have to differentiate sligbtly before they reached a state that compared favorably with the normal basal cells.

Melanocarcinoma arises from cells which have undergone marked dedifferentiation. These cells would have to differentiate to a great extent before they reached a biologic state of development comparable to that of normal cells.

Since cellular differentiation plays such an important part in the grading of malignancies, it is important for the microscopist to be familiar witb any deviation of the cellular structure from the normal.

In the grading of malignant neoplasms, the proportion of cells that are differentiated is compared to those cells which are undifferentiated. The results are expressed thus:

Grade 1 Carcinoma: The proportion of differentiated cells ranges from almost 100 down to 75 per cent; that of the undifferentiated cells, from practically 0 up to 25 per cent.

Grade 2 Carcinoma: The proportion of differentiated cells ranges from 75 down to 50 per cent; that of undifferentiated cells, from 25 up to 50 per cent.

Grade 3 Carcinoma: The proportion of differentiated cells ranges from 50 down to 25 per cent; that of undifferentiated cells, from 50 up to 75 per cent.

Grade 4 Carcinoma: The proportion of differentiated cells is from 25 per cent to practically 0; that of undifferentiated cells, from 75 to 100 per cent.

For a more detailed explanation on the grading of malignancies, the reader is referred to Broders' articles on the subject.

Treatment.—For lesions that are microscopically diagnosed before they become invasive and probably before metastasis has occurred, excision with scalpel or the cutting current would seem to be the method of election. When we encounter a small lesion that we think is or might be epithelioma of the squamous-cell type we excise it with a scalpel. If it cannot be excised in this manner it is done with the cutting current. Naturally, the excision is wide and deep. A careful histologic study is then made to establish diagnosis, to determine the grade of malignancy, to ascertain the degree of invasiveness if any, and the probability of metastasis already having occurred and, finally, to determine whether or not all malignant tissue has been removed. Subsequent treatment depends, naturally, on the result of the examination. When there is no or very little invasion and the malignant cells are well within the excision, no additional treatment is given, but the patient remains under observation. When in doubt, roentgen rays or radium is employed.

Advanced cases may be treated with roentgen rays or radium, with surgical diathermy or scalpel surgery, or with a combination of these methods, according to location, extent of involvement, grade of

Broders'[20] classification explains the difference in the malignancy of the same type of carcinoma in different situations. The grading of malignancies is based upon cellular differentiation. A dedifferentiated cell is one in which the functioning quality is decreased or absent and the reproductive or proliferative quality is increased. The basal-cell type of carcinoma shows that dedifferentiation is slight; therefore,

Fig. 57.—Squamous-cell epithelioma of lower lip.

Fig. 58.—Same as Fig. 57. After surgical diathermy.

Fig. 59.—Squamous-cell epithelioma of lower lip.

Fig. 60.—Same as Fig. 59. After surgical diathermy.

mucous membrane. The second stage includes more extensive lesions with infiltration of the subcutaneous structures but not affecting the lymphatics. The third stage includes those cases having lymph gland involvement. All these cases were treated with roentgen rays alone.

One hundred and eight patients were in the first and second stages. Four of these showed glandular metastasis at a later date and died. Eleven of the cases were in group three and all died. Roentgenotherapy

FIG. 65.—Verrucous squamous-cell epithelioma of lower lip involving left commissure

FIG. 66.—Squamous-cell epithelioma of tongue of a woman.

malignancy, etc. In this country excellent results have been obtained in cases of advanced carcinoma of skin and orificial mucous membranes by Clark, Pfahler,[21] Quick,[22] Wood, Regaud [23] and others with com-

FIG. 61.—Squamous-cell epithelioma of lower lip.

FIG. 62.—Same as Fig. 61. After removal with cutting current.

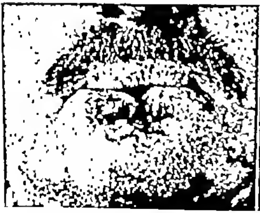

FIG. 63.—Squamous-cell epithelioma of lower lip.

FIG. 64.—Same as Fig. 63. After removal with cutting current.

binations of roentgen rays, radium, surgical diathermy and scalpel surgery.

In a recent article, Martin [24] reports on 119 cases of squamous-cell epithelioma of the mouth and lips. These he classifies in three clinical stages. In the first stage are those cases involving only the skin and

Quick reports 2,741 cases treated over a period of 10 years from 1917 to 1927. Twenty-one per cent are known to be clinically free from gross evidence of disease; 11.8 per cent of the entire group have been free from clinical evidence of disease for periods of three to ten years.

In this period of ten years, 473 tongue cases were treated; 105 are free from clinical evidence of disease, 53 being beyond the three-year period and 32 beyond the five-year period.

Regaud [22] treated 344 cases of cancer of the tongue and floor of the mouth at the Radium Institute in Paris during a period of six years

Fig. 69.—Aphthous ulcer resembling epithelioma.

(1920-1926). Eighty-two of these, or 23.8 per cent, were completely cured. The method used was the implantation of radon in removable platinum-iridium needles—the so-called radium puncture. If the glands of the neck were involved and proved to be carcinomatous histologically, then a block dissection was resorted to with the application of a radium pack at a distance of 5 to 8 cm. from the skin surface. Regaud is of the opinion that distance radiation with a radium pack or a wax mold will supplant the radium puncture method in the treatment of primary carcinomas. By using this method in the treatment of carcinoma of the lip he reports the following results:

A. Operable Cases: 98 per cent cures of the primary localization; 92 per cent cures of cases with cancerous adenopathy (operable cases with glands).

failed to cure all the cases having glandular involvement whether or not they were clinically present.

The treatment is directed toward complete destruction of the local lesion and irradiation of the glands draining the involved area. Complete destruction may be accomplished by surgery, high-frequency currents, or by radium or roentgen rays.

It can be said that there is no method of choice for the treatment of prickle-cell carcinoma. Frequently, the best treatment is a combination treatment of surgical removal and application of roentgen rays or gamma rays of radium. For more detailed statistics and methods of treating cutaneous malignancies, see textbook by MacKee [18] and monograph by MacKee and Cipollaro.[21a]

When carcinoma of the lip or mouth has invaded the cervical glands, Quick [22] treats the neck from both sides with heavily filtered radiation

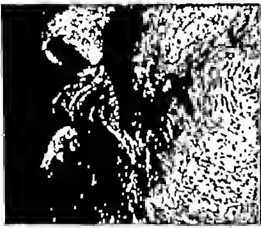

Fig. 67.—Squamous-cell epithelioma of tongue.

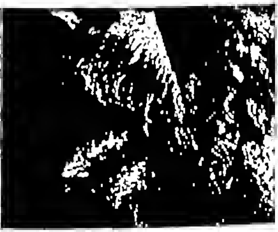

Fig. 68.—Same as Fig. 67. After removal with cutting current.

of maximum intensity consistent with tissue tolerance. Radium is preferred to roentgen rays; but if sufficient radium element or radon is not available, then heavily filtered high voltage roentgen rays should be used, for it is better to give "a good dose of roentgen rays than a poor dose of radium." If only one node is involved and the carcinoma has not invaded the capsule, that node is removed surgically. If after irradiation there is a palpable node, then a unilateral block dissection is indicated. After dissection, filtered radon seeds are placed in suspicious places before the wound is closed. If the involvement is so extensive in the glands that the case is inoperable, then filtered radon seeds are placed throughout the cancer-bearing area. For all practical purposes it can be said that when cancer involves the glands on both sides of the neck, the case is inoperable and hopeless. Heavily filtered roentgen-ray therapy may be used palliatively.

TRANSITIONAL-CELL CARCINOMA

This type of tumor arises from tissues having abundant squamous-cell tissue, as, for example, the tongue, floor of the mouth, tonsils, sinuses, ducts of mucous glands, etc.

The rapidly growing forms of these lesions are difficult to recognize microscopically. Quoting from Ewing,[23] these tumors "probably spring from gland ducts but may also arise from the general stratified layer of cells lining mucous surfaces. They form sheets of rather small cells which are cuboidal or spindle-shaped. They excite little growth of connective tissue. For these reasons they are markedly radiosensitive."

The primary lesion is usually very small, and metastasis is likely to occur early in the adjacent glands. The surface is finely granular and flat, giving the appearance of an erosion rather than an ulcer. Clinical evidence of infiltration is usually absent. This lesion is so small that it is frequently overlooked, and the first evidence of its presence to be noted by the patient may be glandular enlargement.

In the treatment of this type of malignancy, the importance of a biopsy must be stressed. If the microscopic examination shows a transitional-cell epidermoid carcinoma, then the best treatment is radiotherapy combined with surgery. Gold radon seeds may be implanted in the tissues surrounding the primary lesion after its removal with surgical diathermy. Metastatic glands are treated with heavily filtered roentgen rays or radium.

PAGET'S DISEASE

Darier,[24] Pautrier,[3] Fraser [4] and others have made careful studies of Paget's disease of the nipple. As a result of these investigations, while there is no unanimity of opinion, the consensus is that Paget's disease of the nipple is a carcinoma of the intra-epidermal portion of the mammary duct; also, that Paget's disease is cancer from the very beginning. The distinctive microscopic picture inclndes the so-called Paget cell. These are sharply defined, large epithelial cells which contain a single, large, deeply stained nucleus.

Paget's disease of the nipple occurs rarely in men. Most of the cases occur in women. It is an uncommon rather than a rare disease. Both breasts may be attacked. It seldom occurs before the age of 35. Evolution is slow, but sooner or later there is evident carcinoma of the breast with metastasis to the axillary glands.

The clinical picture is not always the same. The usual picture is that of a sharply marginated eczema surrounding the nipple. The eruption, however, does not yield to any of the therapeutic agents employed for eczema, including small doses of roentgen rays. The stubbornness, location, age of the patient, sex, sharp margin, persistent erosions,

B. Cases of doubtful operability including those with glandular metastasis, 72 per cent cures.
C. Inoperable Cases: 17.8 per cent cures of the primary localization considered by itself; 14.2 per cent cures of both primary and metastatic lesions.

Carcinoma of the penis is always of the squamous-cell type. It is found to be more prevalent among those who have not been circumcised in childhood. A tight prepuce is considered by some to be an important etiologic agent. Of all cancers in the male, 1 to 3 per cent are those of the penis. When these lesions are treated early, they respond well to roentgen rays and radium. The vast majority, however, do not seek expert advice until after the disease is quite advanced with involvement of the deep tissues and inguinal glands.

Pfahler and Widmann [21] report nine cures of ten cases treated. Their method consisted, in the majority of cases, of amputation of the penis by surgical diathermy and the application of roentgen rays to the inguinal glands. In some cases, amputation was preceded by irradiation. These results excel those obtained by surgery alone.

Some cancer experts prefer to administer a large dose of roentgen rays or radium to a tumor before the lesion is removed or destroyed with scalpel surgery or surgical diathermy, especially when there is no evidence of metastasis. The rationale of such procedure is that any cells that remain *in situ* or that may enter the blood stream or lymphatic channels have received a dose of radiation that may prove lethal or that will at least be inhibitory. The idea is a good one, but there are no convincing statistics in support of the method.

The dose either of roentgen rays or of radium must, of course, be decided and administered by an expert. Experience has demonstrated the fallacy of producing extensive third degree reactions. In many instances the dose may be well within tissue toleration. In other instances the dose must be very close to the limits of toleration. With roentgen rays, the dose ranges from a few times to many times that required for erythema, depending on the size of the area treated, the age of the patient and particularly the quality of the radiation, i.e., the voltage and amount of filtration. With radium and radon packs (distant treatment), the dose ranges from a few hundred to several or many thousand milligram or millicurie hours. The dose depends on the character of the lesion and the dimensions of the surface to be exposed, the amount of filtration and the distance between the pack and the skin or mucous membrane. When gold or platinum radon seeds or implants are employed, it is customary to implant one seed for every square centimeter of tissue. They are implanted all through the lesion and around its periphery. The amount of radon in each seed varies from 0.75 millicurie to 1.5 or 2 millicuries.

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FIG. 70.—Paget's disease of the nipple.

FIG 71.—Paget's disease of the nipple. (Courtesy of Dr. Josiah P. Thornley.)

infiltration, retraction of nipple and, perhaps, some pain should make one suspicious of the true nature of the affection. Instead of an eczema-like eruption the condition may consist of infiltration of the nipple, or the nipple may be keratotic or verrucous, and is usually retracted. It is unwise to depend on clinical diagnosis. When a nipple or a breast has been normal and becomes abnormal, and the condition does not respond immediately to conventional treatment, a careful microscopic study of the tissue should be made.

Treatment.—Cases have been permanently cured with roentgen rays and radium, but such treatment is uncertain. It is now the consensus of opinion among dermatologists that as soon as the diagnosis is established mastectomy with removal of axillary glands should be performed.

Extramammary Paget's Disease.—Paget's disease has occurred on the penis, scrotum, perineum, pubic region, umbilicus, lip, nose, cheek, forearms, trunk, ears and tongue. In fact, it may occur in almost any location. In such instances, the growth begins in the epithelium associated with the cutaneous appendages. Clinically, extramammary Paget's disease may resemble Bowen's disease, eczema, psoriasis, basal-cell epithelioma, squamous-cell epithelioma and other diseases. As a rule, the diagnosis can be established by microscopic examination.

Treatment consists of removal or destruction of the lesion with surgical diathermy or scalpel surgery.

Fig. 72.—Bowen's disease.

BOWEN'S DISEASE

Originally, this condition was thought to be a forerunner of cancer. It was known as Bowen's precancerous dermatosis. It is now known to be cancer from the beginning—an intra-epidermal carcinoma. There may be a single lesion or multiple lesions. They are most common on the trunk and extremities but may occur in almost any location, even in the orificial mucous membranes. Clinically, they resemble the flat type of basal-cell epithelioma—multiple epitheliomatosis cutis. They have a well-defined margin and a dark-red color. They may be dry and scaly or edematous, exudative and eroded. As a role, there is very little infiltration, especially in the early stages. Evolution is slow and the degree of malignancy is low. Metastasis does not occur. Clinically, the affection must be differentiated from basal-cell epithelioma, squamous-cell epithelioma, eczema, psoriasis, and other dermatoses. The disease can be cured with roentgen rays, radium or with electrodesiccation.

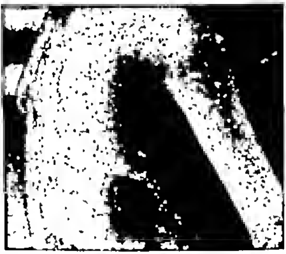

FIG. 73.—Melanoma in a young boy.

MELANOMA

The term *melanoma* is ordinarily used to designate a pigmented malignant neoplasm. Benign melanomas include pigmented nevi, the blue nevus of Tièche and the mongolian spot, while malignant melanomas include melanocarcinoma, nevocarcinoma, melanosarcoma and nevosarcoma. Melanomas probably all arise from a specific mesoblastic cell, the chromatophore. The term *melanosarcoma* has been used incorrectly as a synonym for melanocarcinoma. Melanosarcomas are rare and arise in the choroid coat of the eye and in the blue nevus of Tièche.[264]

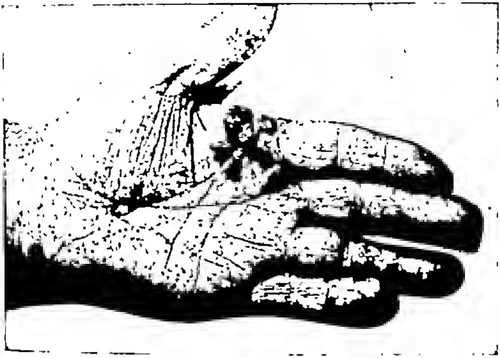

Fig. 74.—Melanoma of the hand.

Fig. 75.—Melanoma of scalp.

Fig. 76.—Melanoma of ear resembling epithelioma.

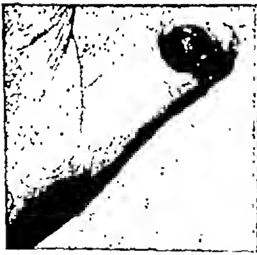

Fig. 77.—Melanoma of thumb—melanotic whitlow.

Fig. 78.—Same as Fig. 77. After surgical and roentgen-ray treatment.

FIG. 79.—Melanoma with metastasis.

FIG. 80.—Melanoma of scalp.

The type of nevus that most frequently gives rise to melanoma is the blue-black or slate-colored, smooth, flat, hairless mole. Metastasis is likely to occur early. The prognosis is grave. Melanomas may occur at almost any age. Occasionally such an innocent condition as granuloma pyogenicum may markedly resemble a melanoma.

Lesions of this type have been cured with roentgen rays and with radium, but such treatment is very uncertain, as melanoma is radio-

FIG. 51.—Granuloma pyogenicum resembling melanoma.

resistant. Perhaps the best treatment consists of the administration of a large dose of heavily filtered radium or roentgen rays, followed by excision with the cutting current. Malignant cells may be found some distance from the periphery of the lesion, especially in the subcutaneous tissue. Therefore, the excision should be wide at the surface and wider below—cone-shaped excision. It should extend down at least to the muscle. The excised tissue should then be carefully examined under the microscope to ascertain, so far as possible, whether or not all the malignant cells have been removed. When diagnosed before metastasis has occurred and before there has been much local spread-

ing, it is possible to obtain a permanent cure. After metastasis has occurred very little can be done. Metastatic lesions soon occur in the viscera and various parts of the cutaneous surface.

SARCOMA

Sarcomas of the skin are the least common of the cutaneous malignant neoplasms. They are formed of immature connective tissue cells. In the nonpigmented tumors, the cells may be of the small or large round variety, spindle-shaped or the mixed-cell type. The small round-cell sarcomas are the most malignant and the fibrosarcomas and giant-cell sarcomas the least malignant. The more the cellular structure resembles adult tissue, the less the malignancy.

The following classification of cutaneous sarcoma has been suggested by De Amicis: [27]

1. Localized or multiple nonpigmented sarcoma.
2. Melanotic sarcoma.
3. Multiple hemorrhagic sarcoma of Kaposi.

Localized Nonpigmented Sarcoma.—This variety is the most benign. It appears as a single localized tumor, pea- to lemon-sized, usually the color of normal skin. Early surgical removal offers the best outlook.

Multiple Nonpigmented Sarcoma.—In this type the lesions vary in number from a few to several hundred. These lesions may develop following the appearance of a single primary growth. They are pinhead- to egg-sized and are round or oval. The overlying epidermis is smooth and shiny, and telangiectases are frequently present. The outlook is serious. Coley's serum may be tried, but it is doubtful if any benefit can be derived from it. Roentgen rays may be used palliatively.

Melanotic Sarcoma.—This is the most malignant of the sarcomas. Lesions usually start in the choroid layer of the eye or in the blue nevus of Tièche. The cutaneous lesions are pinhead- to egg-sized, of a firm consistency and blackish in color. The shape is oval or round and slightly elevated. These cases end fatally practically always, unless detected very early. Coley's serum may be attempted. Little can be done except in a palliative way.

Multiple Hemorrhagic Sarcoma of Kaposi.—This affection is not very malignant. The sites of predilection are the extremities. It occurs most frequently in males. The eruption consists of various-sized, infiltrated, lilac-colored, doughy plaques, or collections of several

The type of nevus that most frequently gives rise to melanoma is the blue-black or slate-colored, smooth, flat, hairless mole. Metastasis is likely to occur early. The prognosis is grave. Melanomas may occur at almost any age. Occasionally such an innocent condition as granuloma pyogenicum may markedly resemble a melanoma.

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FIG. 81.—Granuloma pyogenicum resembling melanoma.

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Fig 85.—Multiple lymphosarcomas.

FIG. 82.—Lymphosarcoma.

FIG. 83.—Same as Fig. 82. After removal with cutting current by Dr. J. J. Eller.

FIG. 84.—Lymphosarcoma of neck.

FIG. 86.—Giant-cell sarcoma.

FIG. 87.—Same as Fig. 86. After excision by Dr. Merlin J. Stone.

FIG. 88.—Spindle-cell sarcoma.

FIG. 89.—Same as Fig. 88. After excision by Dr. Merlin J. Stone.

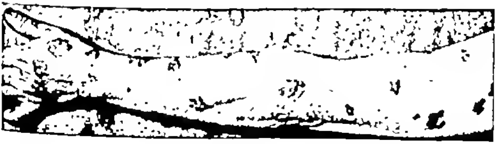

FIG. 90.—Sarcoma of Kaposi type.

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or many firm, bean- to pea-sized, reddish or purplish nodules. Both types of lesions are usually present. Occasionally there is ulceration. Evolution is slow; the lesions persist for months and years; spontaneous recovery may occur. There is always danger of a rapidly growing more malignant type of sarcoma as a complication. Roentgen rays are almost a specific for this disease. Arsenotherapy is said to be of value. (See article by MacKee and Cipollaro.[27a])

Neurogenic Sarcoma.—These are tumors arising from nerve tissue and may appear on any portion of the body. They vary in size from that of a pea to an orange or larger. The color is the same as that of the normal skin. The prognosis is poor. True neurogenic sarcomas have a high mortality and have a tendency to recur along the nerve trunk.

Dermatofibrosarcoma.—Darier [28] reported four cases of dermatofibrosarcoma in 1924. Clinically, this condition is characterized by the development in the skin of small, hard infiltrating nodules which increase in size and number slowly to form a dense sclerotic, bluish plaque. Later on stalked, pedunculated or sessile nodules and tumors project from this plaque. These neoplasms are hard and may reach the size of an apple. The tumors are apt to recur after removal. Darier [28] gave this condition the name "progressive and recurring dermatofibrosarcoma." It is asymptomatic, does not affect the general health and does not metastasize.

It is difficult accurately to classify these tumors histologically. The picture is that of a fibromatous growth resembling very closely a spindle-cell sarcoma in certain cases.

The tumors are radioresistant; in fact, they do not respond to any form of therapy except as in the cases reported by Senear, Andrews and Willis,[29] in which there was no recurrence after complete excision of the mass.

Melanotic Whitlow (Melanoblastoma of the Nail Bed).—This is a malignant disease of the nail bed, which is characterized by the formation of nodules of neoplastic tissue with associated formation of melanin about the border and beneath the nail. These lesions are painful and the majority of the victims die in from four to ten years.

Early surgical removal or amputation is the treatment of choice.

Lymphosarcoma.—This condition usually arises in a single chain of lymph glands and occurs late in life. Lymphosarcoma is very malignant and markedly susceptible to radiation. The glands most frequently involved are the cervical and axillary glands. If neglected, these go on to ulceration.

Since this disease is radiosensitive, roentgen rays and radium are indicated. In some cases, isolated involved glands may be removed surgically.

FIG. 92.—Mycosis fungoides.

FIG. 91.—Sarcoma of Kaposi type.

FIG. 91.—Mycosis fungoides.

FIG. 91.—Sarcoma of Kaposi type.

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Fig. 93.—Lymphoblastoma.

Miscellaneous Malignant Diseases.—The Spiegler-Fendt sarcoid is thought by some to be a benign type of sarcoma. Serious diseases of the hematopoietic system and reticulo-endothelial system may cause tumors of the skin—leukemia cutis, Hodgkin's disease, mycosis fungoides, lymphoblastoma, etc. Many such conditions are temporarily amenable to roentgen-ray and radium therapy.

CHAPTER NINETEEN

ELECTROSURGICAL CURRENTS AND THE HISTOLOGY OF ELECTROSURGICAL WOUNDS

John D. Ellis, M.D.

For surgical purposes, a high-frequency current is an oscillating current having a rate of frequency above the threshold which produces faradic response, due to conduction of the current into the tissues. Its virtue lies in the effects resulting from the resistance of the tissues to the current, which manifests itself in the formation of heat and the local destruction of tissues of various and peculiar types.

It is my purpose to deal with a distinction in effect upon tissues of the so-called cutting current and the coagulating current, in so far as such distinction can be made, and, in a rudimentary way, with the distinction in the quality of the current which produces the cutting and coagulating effects. The production, technic, and tissue effects of fulgurating and dehydrating currents will be more briefly described. The commercial machines produced by different manufacturers vary greatly in construction and produce a correspondingly great variety in the quality of current. The ohmic resistance is often too great or too little to give the desired effect, and undesirable secondary faradic currents, with their resultant neuromuscular response, are experienced when improperly constructed machines are used. For example, it appears that the only way in which the sustained oscillating current of radiotron machines can be employed for coagulating purposes is by raising the amperage and voltage to a point where charring of the tissues, which prevents a dissemination of the coagulating effect, soon results. On the other hand, the spark-gap machine produces a current from which it is difficult to eliminate the coagulating effect of the damped current inherent in the spark-gap machine. The present lack of standardization is unavoidable because of the difficulty in accurately measuring amperage or voltage during operation of the machine, so that the proper strength of current used for coagulation or for cutting must be learned by experience with each individual machine.

A very nice balance must be maintained between voltage and amperage, and also the capacity, inductance, and resistance must enter into the determination of the particular current used.

Doyen's earliest machine, producing a high voltage and high frequency of oscillations but a low amperage, was equipped with a transformer, spark gap, and condenser, attached in circuit with an Oudin

therefore, undamped oscillations. The oscillating currents from radiotron machines present a precisely determined wavelength. In contrast to this, the oscillations of the spark-gap machines are composed of a mixture of waves of different lengths. It is not to be supposed that in actual practice damping is the only factor which distinguishes the cutting from the coagulating current. The elevation of both amperage and voltage within certain limits, produces more coagulation, while the increase in frequency in the undamped current up to a certain optimum of several million per second tends to produce a more smooth and uniform cutting effect. The duration of the application of current to tissues and the density of current, as conditioned by the size and shape of the active electrode or cutting point, also function in the determination of the extent of the area of coagulation. By lowering the voltage of the coagulating current to a minimum, the slow heating effect on tissue produces what Clark called electrodesiccation, a dehydrating change without electrocoagulation.

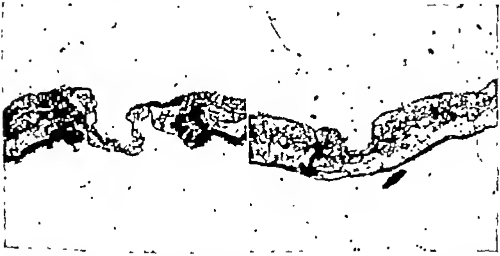

FIG. 1.—Skin of frog incised with a minimum amount of cutting current presenting section with a thin layer of coagulation such as would not be expected to prevent primary union.

FIG. 2.—Frog skin divided with a dehydrating current. The epidermal cells adjacent to the cut are changed in orientation; x 36.5

General Effects of the Cutting Current on Tissues

The technic of electrical cutting is the most recent development in electrical surgery. Smooth cutting depends, in part, upon the frequency of the oscillations, and upon the adjustment of a spark-gap machine to a frequency of 50,000 to 80,000, while with a radiotron machine exhibiting a frequency of often more than 1,000,000, the knife electrode can be handled just as a plain scalpel. The electrode glides through the tissues without the necessity of pressure. One has

coil. Later he used the entire solenoid (Oudin coil) as a secondary coil, taking the current off at both ends, producing the so-called biterminal current. The earlier machine supplied a fulguration current, while the later one furnished the current we now call electrocoagulating. Charring of tissues in fulguration prevents penetration of the coagulating effect.

The Cutting Current

The production of the cutting current came many years later, and is just now being widely discussed in German literature by Kuecken and Doederlein in the Gynecological Clinic of the University of Munich, and by Keysser, a former associate of Lexer. The principal French contributors are Champy and Heitz-Boyer, while in England some experimental work has been undertaken in London by Sampson Handley, Gordon Taylor, and Douglas Harmer. In America, several important surgeons are now interested in the possibilities of the cutting current.

This cutting current depends, for its peculiar surgical effects and characteristic tissue changes, upon the amount of damping—or, rather, lack of damping—of its wave trains. It is safe to say that the more nearly a perfect, sustained, uninterrupted oscillation is exhibited, the more nearly the wound produced approximates that of a surgical scalpel. The exact wave forms produced by the various surgical machines during their application have not yet been actually photographed with a cathode ray oscilloscope because of technical difficulties in projecting the shadows of the individual wave of oscillations at such high frequency as the ones now used, and because these oscillations are affected by various adventitious factors of damping and secondarily induced wave forms.

The production of a high-frequency surgical current depends upon the oscillation of electrons, which perform a pendulum-like movement. There are two fundamentally different methods of obtaining these oscillations. In the first, just as the swinging of a pendulum gets smaller and smaller on account of the friction resistance, so in the spark-gap machine the oscillations of the electrons slowly decrease, because in the spark gap they are damped by air resistance. We deal, therefore, in spark-gap machines, with damped high-frequency oscillations. In the second method, undamped oscillations are generated by means of radiotrons. These machines employ the same radiotrons or radio tubes which are used in the wireless and in broadcasting. We know that in radiotrons a pure current of electrons is flowing, which is rhythmically influenced by the continually changing charge of the grid between the anode and the cathode in the tube. This is the mechanism by which sustained oscillations are generated. Since the radiotron is evacuated as far as possible—that is, free from air—the oscillations are not damped by air resistance of any kind, and are,

The Dehydrating Cut

By a slight change in voltage and amperage, a cutting current can be reduced with enough coagulating characteristics to seal the smaller blood vessels along the edge of the cut in an area of so-called dehydration, which is white and presents cells with shrunken contour and pyknotic nuclei, the fluid contents having evaporated. The skeleton contour of the cells is distinguishable. The cytoplasm stains vividly, while the nuclei are hyperchromatic.

General Effects of the Coagulating Current on the Tissues

This tissue effect is produced par excellence by a high amperage and a strongly damped current in a spark-gap machine, or by raising the voltage and amperage of the radiotron machine. A lower frequency of oscillations is necessary than for cutting purposes. Widespread coagulation can easily be produced with a spark-gap machine without charring or carbonification of the edges of the wound (Fig. 3). In the use of this, as in the cutting current, the electrode is brought in contact with the tissues, and then the circuit is closed. If the circuit is closed before the contact is made, sparking across from the electrode to the tissues may result in charring. This zone of charring interferes with the dissemination of the coagulating current and limits the coagulating effect. It is also improper to remove the electrode from the tissues until the current is opened. This sparking from the electrode to the tissues, besides the charring effect, also induces faradic extra currents and muscle jerking, which interfere with the delicacy of the operation. Small areas of coagulation assume the form of a half globe or an inverted cone, the base of which is on the surface of the tissue being cut. Two definite zones can be described in the coagulating effect. The inner zone is blanched and the zone external to this is hyperemic in appearance. The inner zone, in histologic preparations, presents a blue nuclear staining, e.g., hematoxylin, contrasting with the red eosin staining of the intact tissue. The tissues so affected are somewhat shrunken and the nuclei have lost their definition and stain poorly, or disappear. This is the typical picture of coagulation necrosis. The proteins are split, freeing blue staining acid radicals with a probable increase in the local hydrogen potential. According to Doederlein, the protein hydrosol is changed into a hydrogel. This inner zone passes over into an ill-defined outer zone of shriveled cells with pyknotic nuclei and a region of dilated vessels. "The faster the tissue dies, the more it conserves its original form and shape" (Ernest). The primary effect of the heat is identical with necrosis of ordinary skin burns. This applies to preparations made immediately after the operation. Preparations made several hours or days later show the outer zone being invaded by fibroblasts, round-cell accumulation, and for-

the impression that the tissue melts under the influence of the electrical current. Kirschner, for this reason, has given it the name of "melting cut." This incision has the gross appearance of a scalpel cut (Figs. 1 and 2). Kelly has called this procedure "acusection," and Keysser has described it as "akutomy." The histologic effects on tissues can be described in zones, the innermost being a zone of mechanical disruption of tissue and explosion of cells. The question of whether this effect is produced by molecular dissonation, due to the assumption by the molecules or atoms of the tissues of a new rate of vibration, causing dissolution of the molecular structure, as postulated by Oudin, or whether it is merely a thermal effect due to the sudden expansion of the cell when its liquid contents are converted to steam, as Jellinek thought, is speculative and need not interest us here. Just outside of this zone of tissue disappearance is a zone of elongation or attenuation of cells, this drawing-out effect being seen principally in the nuclei which are more fluid than the cytoplasm. Kawamura described radiating lines of similarly attenuated cells running out from areas of electrical injury in fatal cases. Depending upon the fluidity of the tissues, there is a varying amount of change in the orientation of these elongated cells, so that they come to lie parallel with the direction of the cut. This effect is seen at its maximum in soft connective tissue or muscle, and cannot be produced in the stratum corneum of the skin. In parenchymatous organs, this elongation is transmitted along the nearby blood vessels, perhaps because the tissue surrounding the vessels is less resistant than the vessel wall itself.

Wildermuth, assuming the resistance of a chemically pure physiologic salt solution of a temperature of 18° C. (64.4° F.) as 1, estimates the specific resistance of the various tissues as follows:

Fatty tissue	19.4
Brain tissue	5.5– 6.8
Pulmonary tissue	3.5– 4.0
Liver tissue	2.8– 3.3
Skin	2.5– 3.0
Muscle	1.2– 1.5
Blood, approximately	1.0

The higher the fluid or blood content of an organ, and the lower its fat content, the less its resistance to electric section. The great resistance in cutting through fat, as compared to muscle and skin, at first disturbs the surgeon habituated to the scalpel, which cuts fat more readily than muscle and skin. The variation of resistance to electric cutting necessitates a readjustment of the machine as one passes from s' n into fat, and then into muscle or parenchymatous organ.

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eign body giant-cell formations. Robertson and Boyd have isolated from the tissues coagulated by heat two immunologically specific toxic proteins. One, diffusible and thermostable, they term a "neurotoxin," and the other, thermolabile and colloidal, a "necrotoxin." Pfeiffer, and Becky and Schmitz have isolated a toxic protein from the urine.

FIG. 3.—Dog skin to which has been applied an electrode bearing the least amount of cutting current which would leave a visible mark on the surface. A wide wedge of necrosis results with less current than is required to sever the skin. Fragmentation of a hair is seen. Vacuolization appears in the corium; x 65.

It is probable that these toxins produce the outer area of secondary necrosis.

Nieden has pointed out that deep coagulation, even in the inner zone of complete necrosis, is always uneven. In experiments in association with the physicist Weiss, he tried to account for the unevenness and the direction of penetration according to the distribution of stream lines produced by different shapes of electrodes and marked variation of resistance displayed by the various tissues. This variation makes the direction of penetration and deep coagulation unpredict-

able, and the resulting tissue injury one of the most dangerous factors one deals with in electrosurgery. After coagulation in the vicinity of large vessels, a fatal postoperative hemorrhage may occur as the result of an unexpected necrosis of the vessel wall.

Specific Effects on Different Tissues

Skin preparations were first studied in our experiments to determine the type of injury produced by the minimum amount of cutting and coagulating current which would leave a visible impression on the surface. Later, attempts were made to incise the skin of the human,

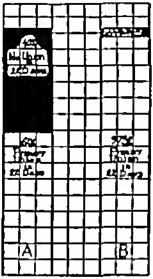

FIG. 4—Comparison of primary unions between electrosurgical knife wounds, *A*, and scalpel control wounds, *B*. (Reprinted from J.A.M.A. 96: 16–18, 1931.)

dog, rabbit, and frog with a current producing a purely cutting effect without necrosis. In all skin possessed of a stratum corneum, i.e., in all types employed except that of the frog, specific cutting effect without coagulation could not be accomplished. A narrow margin of coagulation bounded every incision, although this was narrower (a minimum of 1 mm.) with the cutting than with the coagulating current. The stratum corneum, then, resists the disruptive effect of the cutting current until enough heat is produced by tissue resistance to cause coagulation. At the time of incision, the epidermis is blanched and is thinner because it is shrunken. The individual epithelial cells can no longer be discerned plainly in the stratum corneum, while in the strata mucosa and germinativa, the cells assume somewhat the appearance of those in a normal corneous layer. The cells in the basal layers are shrunken together and have dark, spindly nuclei. The fibers of the connective tissues of the corium are either coagulated adjacent

to the cut or have lost their fibrillary structure and appear as conglomerate masses, often resembling hyalin in appearance. They can no longer be dyed red in a hematoxylin-eosin preparation, but turn slightly blue. Between these close-pressed masses appear shrunken nuclei. When the cut reaches into the fat, only the connective tissue of the fat is changed, the fibers being broadened, dyed blue, and con-

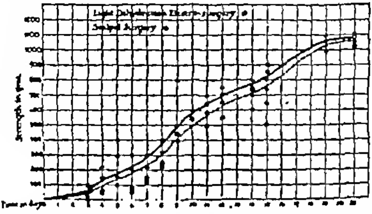

FIG. 5.—Tensile strength of wound healing in skin of dogs: The strength of healing never varies more than 100 Gm. average between the scalpel wound and the electrical wound. (Reprinted from J.A.M.A. 96: 16-18, 1931.)

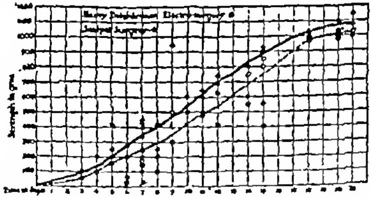

FIG. 6.—The tensile strength of wound healing in skin of dogs: The strength of healing is less when heavy dehydration (or electrodesiccation) is applied than when slight dehydration is used, as in Fig. 5. (Reprinted from J.A.M.A. 96: 16-18, 1931.)

taining pyknotic nuclei. In the stratum reticulare of the corium, flattened gas bubbles appear. Keysser and Schridde seem to be the first to describe this phenomenon, and Schridde saw it also in the epidermis. In the skin of the rabbit, connective-tissue changes extend around the sweat glands at some distance from the region of the incision, and the hairs are fragmented in the changed area around the cut.

The necrosis produced by the minimum of coagulating and cutting current which will leave a visible impression on the surface of all

the skins provided with a stratum corneum presents no difference in type of tissue injury from that of coagulation, described above. We conclude, then, that it is not possible to produce a purely cutting effect without some necrosis on a skin with a horny layer. This slight necrosis produced by the cutting current does not, however, always preclude healing by primary intention, as I found in another experiment performed to test the tensile strength of wound healing on dog skins. In this experiment 60 per cent of electrically produced wounds showed primary union in comparison with 97.5 per cent of primary

FIG. 7.—Complete section of intestinal wall of dog with cutting current without necrosis; x 15.5.

union in scalpel wounds (Fig. 4). When union did occur, however, the electric wounds were somewhat weaker than the knife wounds until approximately the twenty-fourth day of healing. Figure 5 represents in a broken line the strength (expressed in Gm.) of union of centimeter length cuts, pulled apart with a tensiometer on different days of healing of dog skin. This curve represents the 60 per cent of the electric cuts which healed by primary intention. The continuous line represents the 97.5 per cent of scalpel wounds.

It will be seen that in the mid-period of healing, the electric wounds are notably weaker. At 24 days, the two curves have not yet approximated, when heavy dehydration is employed (Fig. 6).

The effects of the cutting current on skeletal muscles and the muscular wall of the stomach and intestines were studied. Incisions may be freely made without any zone of coagulation whatever. There are

a change of orientation and shape of the superficial cells and a sealing of the capillaries and lymphatic channels. These incisions heal with approximately the same tensile strength as cuts made with a scalpel, and without secondary necrosis or infection (Fig. 7). Figure 8, representing tests on muscle section and healing, shows no important weak-

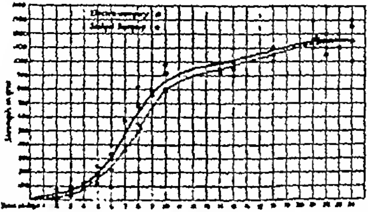

FIG. 8.—Tensile strength of wound healing in muscle: Incisions were made with very slight electrodesiccation; the electrical incisions show almost the same strength of healing as the scalpel wounds. (Reprinted from J.A.M.A. 96: 16-18, 1931.)

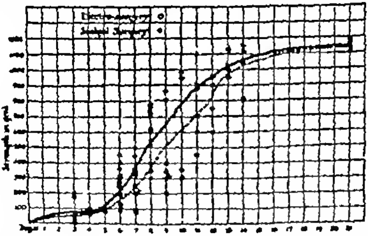

FIG. 9.—Tensile strength of wound healing in stomach: The middle values are decidedly weaker in the electrical incisions; there is a wide variation in all the readings of dogs operated on. (Reprinted from J.A.M.A. 96: 16-18, 1931.)

ness of the electrical wounds at any period of healing. Figure 9, a comparison in healing of electric and scalpel gastrotomy, presents curves of healing for the electric wounds, considered both as to rapidity and time of attainment of maximum strength, entirely comparable to the scalpel wounds of the muscle wall of the stomach.

Primary [illegible] dermal healing presupposes two factors, i.e., a deposition of a c[illegible]lete fibrillary fibrin across the wound and satisfactory

fibroplasia. Baitsell, Hertzler, and Hartwell have shown that fibrin and collagen are deposited in primary healing by a chemical reaction from prefibrin by the absorption of the edema fluid of a wound (Fig. 10). This appears to them to be entirely independent of cellular activity and conditioned by the hydrogen potential of the wound. Fibroplasia occurs first by stereotropism of wandering tissue cells or clasmatocytes along the fibrin network, and later by proliferation of these cells, producing fibroplasia. This mechanism was described in 1914 by Harrison, and the work has been studied and corroborated

FIG. 10.—Primary healing of stomach wall of dog without a zone of necrosis after section with cutting current; x 13.

recently by Baitsell, Wereschinski and Carrel. The last has shown that the formative stimulus to fibroplasia is not found in the blood plasma, but is a local product of the injured tissues. Baker and Hammett, working in Carrel's laboratory, found that the formative stimulus does not depend upon the amino acids that the wound or adjacent tissue contains, but is a protein cleavage product containing a sulfhydryl group. The elaboration of this essential stimulus for cell multiplication is apparently not interfered with by the application of the cutting current to muscle or stomach, and, in some instances, to skin. The production of a fibrillary fibrin network is generally not demonstrable after electrosurgery. Following the advice of Hertzler, I attempted to demonstrate this network with a Weigert-Pal stain, and later with the Kolschetzski modification, but found only a granular fibrin deposition, such as one sees in wounds healing by granulation.

The coagulating current, applied to skeletal muscles and stomach, produces the same inverted zone of coagulation as described in the deeper layers of the skin. The appearance of the coagulated muscle after a few days resembles hyalin in a necrotic area ultimately surrounded by a connective-tissue capsule or absorbed and replaced by fibrosis.

Specific Effects on Blood Vessels

The discussion of the effects of these currents on the blood vascular system can be divided, for clinical purposes, into:

1. Capillary hemostasis in vessels of the size which do not usually bleed after the hemostat is removed in ordinary surgery, e.g., laparotomy wounds
2. The coagulation of moderate-sized vessels, such as the ones which must be ligated before the hemostat is removed
3. The closure of arteries and veins of the size of the radial artery, or larger

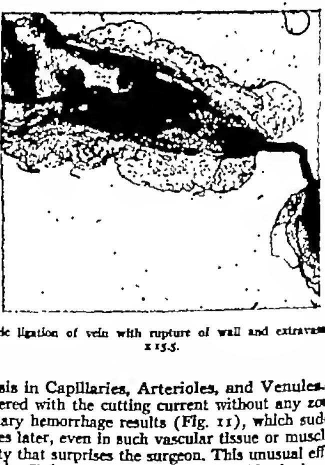

Fig. 11.—Electric ligation of vein with rupture of wall and extravasation of blood; x 15.5.

Hemostasis in Capillaries, Arterioles, and Venules.—When tissues are severed with the cutting current without any zone of coagulation, capillary hemorrhage results (Fig. 11), which suddenly ceases a few minutes later, even in such vascular tissue or muscle or kidney, with a facility that surprises the surgeon. This unusual effect was first investigated by Heitz-Boyer, who noticed, in histologic preparations, the transm· ·ion of elongation and stretching of the cells of the peri-

vascular sheath to a point several millimeters from the cut end of the capillary. There is an abrupt change in the muscular wall of venules and arterioles, causing contraction and fusion with obliteration of the lumen at the point of severance. The arteriole, in particular, often becomes tortuous for a few millimeters (Fig. 12). The vascular lumen is occluded by the collapsed walls and the few epithelial lining cells which are torn off and seen free in the lumen. In some specimens, no endothelial changes are seen except a curious, wave-like wrinkling in transverse ridges just at the point where the lumen begins to contract. It did not appear to Heitz-Boyer that the existence of a few avulsed cells in the lumen was sufficient to account for the sudden hemostasis

FIG. 12.—Correct electrical collapse of arteriole; x 30.

in the capillaries and arterioles after cutting, and it was suspected that there must be a rapid and abundant liberation of thrombokinase from attrition of the vascular wall. The following experiment was undertaken: The serum of rabbits' blood was placed in paraffined tubes. Small, well-polished pipettes were introduced into rabbits' veins and arteries without touching the edges of the wounds of entrance. These vessels were then severed 1 to 2 cm. from the pipette point with undamped current and with the scalpel. The pipettes were withdrawn and placed in the tubes containing serum. The pipettes from the vessels electrically damaged caused immediate coagulation of the serum, while those from the vessels with the knife wounds caused no coagulation of serum for 10 to 12 min., which is the same time that coagulation occurred in the control rabbit serum. They inferred from this that abundant thrombokinase was liberated from the smaller vessel walls by the action of the electric current.

Electric Ligation of Small Vessels.—Vessels of a size which must be ligated to control hemorrhage in ordinary surgery are not generally successfully obliterated with a cutting current. Either they must be touched with a coagulating current, or the hemostat which occludes them must be touched, in order to produce successful hemostasis. The less the tissue surrounding the vessel is gripped with the hemostat, the less the area of necrosis formed. The smaller the amount of necrotic tissue, the greater the chance of absorption of this tissue without a slough, and the less the chance of infection or secondary

FIG. 13.—Correct "electrical ligation" of artery. Convolution of intima without desquamation at point of closure. The most notable changes seem to be displayed in muscularis and elastica; x 19.5.

hemorrhage from the coagulated vessel. We experimented in coagulation of the splenic vessels and the radicals of the superior mesenteric vessels adjacent to the small gut in the dog and found that these were best occluded by use of the coagulating current (Fig. 13). The walls present the same changes that occur in the capillaries on section. It is possible, however, to exhibit enoogh coagulating current to break the vessel all into fragments and produce hemorrhage, or to explode the brittle, collapsed, and constricted wall a few millimeters from the region of hemostasis. As one becomes more efficient, there is a temptation to employ more voltage and a shorter time. This is dangerous. It is easy to generate a cloud of steam at the point of application which pushes into the vessel lumen, exploding instead of sealing it. It is my opinion that the successful coagulation depends upon the

mechanical effect of constriction of the lumen, and not on thrombus formation. The cells of the muscular layers appear crowded together and stained blue. There are the usual nuclear changes which accompany electric coagulation. The intima is seldom avulsed and few free epithelial cells appear in the lumen (Fig. 14). If the vessel is coagulated in the solid tissue of an organ, the vessel change does not extend beyond the tissue necrosis in the parenchyma of the organ. This limitation of change was first described by Kuntzen and Vogel, who carried out experiments upon rabbits. A lobe of the liver was fixed in

FIG. 14—Corrugations of intima, *A*, with contraction of muscle walls in electrical hemostasis; x 85.

the abdominal wall and excised with a coagulating current. The animals were killed on various days. The portal vein was injected with India ink. Thrombi were found to form only as far as the tissue necrosis in the surrounding liver substance. An elective depth effect of the current upon blood vessels did not manifest itself beyond the region of coagulated liver. No secondary hemorrhages occurred along the vessels. This agrees with my experience.

Sealing of Larger Vessels.—Tinker has described the coagulation of the blood in these larger vessels extending 12½ mm. along the lumen. We were unable to demonstrate any such thrombosis in arteries. In veins, a definite coagulation extended not farther back than a

distance equal to the diameter of the lumen when the vessel was coagulated with a current strong enough firmly to close, but not entirely destroy, the vessel. Even after several days this small, red thrombus was still seen in the vessel merely as a coagulation thrombosis, the definition of many of the red cells being retained and the white cells appearing unchanged in morphology. There is no progression in the size of the thrombus, examined several days after the occlusion of the vessel. According to Aschoff, this coagulation thrombosis is in sharp contradistinction to true thrombus formation, which he describes as conglutination and agglutination thrombosis. This latter process presupposes the local heaping-up of platelets, which process is one of the two primary factors in thrombus formation, the other being stoppage of the blood stream. In my opinion, the strength of the hemostatic effect in these larger vessels is determined by the shrinkage and collapse of the vessel wall, and not by pressure from thrombus formation in the vessel. Based on the idea that satisfactory sealing of these vessels is accomplished by shrinking of the wall, Harvey Cushing has originated a novel manner of dealing with them in neurosurgery, which is applicable in any region where the vessel is exposed and free from the solid organs. A ball electrode, about ⅛ in. in diameter, is used in connection with the usual coagulating current of a strength appropriate to the size of the vessel. Beginning at the clamped section of the vessel, its surface is gently stroked in a series of short strokes, which results in pushing the contents of the lumen back and sealing the vessel shut as one proceeds.

Conclusions

The effects of high-frequency currents used in surgery depend definitely on the qualities of the current employed. Two types of electrosurgical machines are in common use, one in which the frequency of oscillation is produced by multiple spark gap and the other by radiotrons or radio tubes. The first always produces a somewhat damped current. The less the damping, the more nearly the current produces a clean cut, like an ordinary scalpel wound; the more the damping and the higher the amperage, the greater the amount of coagulation produced in the tissue at the edges of the incision. Both the cutting current and the coagulating current have special indications and advantages in surgical practice. The radio knife can be made to produce a cut without coagulation, as the current is not damped. By increasing voltage and amperage in this machine, a coagulating cut can be produced, but this is likely to be associated with charring and prevents penetration of the coagulation into the tissues.

Experimental cuts were made with both types of current on the skin of the human, dog, rabbit, and frog. The first three of these have a skin with a stratum corneum, and, in the presence of this layer, some coagulation results before penetration of the skin can be accom-

plished, even with a pure cutting current. This coagulation does not necessarily interfere with primary healing, but only 60 per cent of the cuts produced in dog's skin healed by primary intention. The skeletal muscles and the muscular layers of the stomach and intestine can be severed with a cutting current without coagulation. The phenomenon of vessel closure with a coagulating current is an interesting one, involving collapse, shrinkage, and agglutination of the vessel walls without extensive thrombus formation. A large amount of thrombokinase seems to be liberated in cutting capillaries and small vessels. There are many serious errors to be avoided in coagulating vessels. Too rapid coagulation causes explosion and subsequent hemorrhage.

In coagulation of tissues, the specific resistance of the tissues varies tremendously, e.g., fat is more than eight times as resistant as muscle, making the direction of deep coagulation uncertain.

The present tendency in electrosurgery is toward the use of cutting currents and away from massive coagulation as being unsurgical and dangerous.

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CHAPTER TWENTY

ELECTROSURGICAL METHODS

WILLIAM L. CLARK, M.D.

The value of electrosurgical methods in general surgery has been established. These methods are gradually coming into more general use and are growing in importance to the surgeon. Owing to this fact an exposition of the newer units is herewith presented for the information of physicians not yet familiar with their advantages and disadvantages. The present chapter will deal with the more useful electrosurgical methods, upon the basis of the effects produced in the tissues, which will be classified as electrodesiccation, electrocoagulation, and the high-frequency knife.

ELECTRODESICCATION AND ELECTROCOAGULATION

There is an impression among many of the profession that the electrodesiccation and electrocoagulation methods are one and the same. This is an error, inasmuch as the effects produced on the tissues are quite different, and these can be readily demonstrated both clinically and histologically. The type of high-frequency current by which electrodesiccation is produced is of relatively high voltage and low amperage, whereas the current by which electrocoagulation is produced is of lower voltage and higher amperage. This variability in factors permits the surgeon to utilize the current to best advantage in a wide range of neoplastic lesions.

Electrodesiccation.—The electrodesiccation effect produced by the application of one of the forms of high-frequency currents to the tissues was first recognized by the writer in 1908, and it was described by him before the American Electrotherapeutic Association in Saratoga Springs, N. Y., in 1910. It was demonstrated that benign or malignant growths of small or moderate size can be destroyed by the utilization of heat of just sufficient intensity to electrodesiccate or dehydrate the tissues. The heat for the purpose is produced by a monopolar high-frequency current of the Oudin type, the current being conducted to the lesion by means of a steel needle or other pointed metallic applicator. Either a single or a multiple spark gap may be employed in the circuit, but it must be so constructed as to be subject to refined regulation. The proper current strength necessary to destroy growths of different types and sizes can be learned best

from actual experience. The electrodesiccation effect may be produced in the tissues either by delivering the current through a short air space to the growth to be treated, by touching the surface with the electrode without an air space intervening, or by inserting a needle electrode more or less deeply, the method of application depending upon the type of case under treatment, whether the affection is superficial or deep, and also upon the degree of tissue destruction desired.

FIG. 1.—Multiple moles of face.

FIG. 2.—Illustrating the cosmetic result obtained after removal by the electrodesiccation method. When the operation is well performed there is seldom a resulting contracted or elevated scar.

FIG. 3.—Early basal-cell epithelioma of the face.

FIG. 4.—Result of [illegible] electrodesiccation operation; no recurrence after 18 years; patient still living, a[illegible] years.

The electrodesiccation method with modification of technic is used advantageously when the lesion is comparatively superficial and localized, and when it is desired to avoid a contracted cicatrix. It is subject to such control that if the technic is correct, an exceedingly small growth, even on the cornea, can be successfully treated without impairment of vision, or the subsequent formation of discernible scar tissue. A small growth on the vocal cords may likewise be destroyed without impairment of the voice. Likewise, such a delicate structure as a hair follicle may be destroyed quite as accurately by electrodesiccation, if correctly employed, as by the electrolysis needle.

The electrodesiccation method has been found to be most satisfactory for the treatment of localized epitheliomas or sarcomas occurring

FIG. 5.—Extensive basal-cell epithelioma, temporal region, including some bone and outer canthus of eye. This patient had received intensive treatments by both radium and x-ray. Temporary healing, but recurrence; resisted radiation treatment after that.

FIG. 6.—End-result of one electrocoagulation operation, under ether anesthesia. No recurrence in three years; patient died of pneumonia.

upon cutaneous surfaces or accessible mucous membranes. If the lesion is extensive and of a very malignant character, wide resection after electrodesiccation with the electrosurgical knife is a practice to be recommended. Likewise, electrodesiccation can be employed advantageously, with a good curative and cosmetic effect, in the treatment of such benign lesions as warts; moles; nevus vasculosus and pigmentosus; angiomas; tattoo marks; xanthomas; lupus vulgaris and erythematosus; chronic varicose ulcers; localized infections, such as carbuncles; certain cases of exostosis, as of the hard palate; epulis; leukoplakia; papillomas; urethral caruncles; cervical erosions; endocervicitis; hemorrhoids; infected tonsils, and some other lesions.

While in competent hands electrodesiccation has been successfully used in all the above-mentioned lesions, it might not be the best policy to employ it in every such case. Some of the conditions might even

be aggravated if the method is employed by one not experienced in its use. Electrodesiccation is therefore but one other method from which to choose after a correct diagnosis has been made by surgeons conversant with its uses and limitations.

Electrocoagulation.—Electrocoagulation is produced by a bipolar high-frequency current of the d'Arsonval type. The term diathermy is generally employed to identify the d'Arsonval current. The definition of diathermy approved by the Council of Physical Therapy of the American Medical Association is as follows: "A term employed to designate the use of a high-frequency current to generate heat within some part of the body. The frequency must be greater than the maximum frequency producing neuromuscular response. The oscillations may be a frequency ranging from several hundred thousand to several million cycles per second. When such a current is passed through the body at a sufficient voltage and amperage, the resistance offered by the tissues intervening between the electrodes causes heat to be generated in such tissues. It was d'Arsonval who demonstrated that passage of high-frequency electrical currents through living tissues causes neither direct nor indirect contraction of muscles, but does cause the tissues to become heated. Nagelschmidt, of Berlin, in 1907, apparently was the first to apply this property to human beings for therapeutic purposes, and to give it the name of diathermy—'heating through.' The rise in temperature depends not only on the amount of energy absorbed, but also on the efficiency of the circulation in carrying off the heat and maintaining normal temperature."

Either a single or a multiple spark gap may be employed for electrocoagulation, but a good multiple spark gap is preferred, since the current can be "stepped up" by its use. The current producing electrocoagulation is more penetrating and intense in action than that producing the electrodesiccation effect; in accessible locations it is utilized to destroy larger tissue growths; it is also useful in cases where there is extensive bone involvement.

There are many variations of technic in the application of the electrocoagulation method to suit the requirements of individual cases. These variations cannot very well be described with sufficient clarity to permit one to practice them without other study. They must be learned from practical experience as well as study if one expects to excel in their use. The technic for the uncomplicated case of some of the electrosurgical operations will, however, be described later on in the chapter. These descriptions will guide the beginner, but the information given, for reasons stated previously, must necessarily be rudimentary.

Whether electrodesiccation or that phase of diathermy designated as the electrocoagulation method is employed, the aim should be to destroy the growth completely at a single operation. In lesions involv-

ing cutaneous surfaces, the devitalized tissue should, as a rule, be removed immediately, either by excision or curettage, which usually can be accomplished without hemorrhage. In some instances it is best to permit the electrodesiccated slough to separate naturally without curettage or excision. For example, it is best not to excise or curette an angioma after electrodesiccating it. The instrument used for excision should, if possible, cut through the tissues already electrocoagu-

FIG. 7.—Very advanced basal-cell epithelioma involving cheek, osseous structures, and parotid gland. Had resisted x-ray treatment.

FIG. 8.—Result of one electrocoagulation treatment under ether anesthesia. Note absence of contracted scar, without skin grafting; remarkable owing to the great extent of the disease; no recurrence in 15 years.

FIG. 9.—Showing photograph of same patient taken 12 years after treatment

lated, and not through the viable tissues beyond it. If necessary, the base may then receive further electrodesiccation or electrocoagulation treatment.

Excision or curettage immediately following electrodesiccation or electrocoagulation is practiced less frequently in lesions within the mouth, or on mucous membranes elsewhere, than upon the skin surface, owing to the greater possibility of secondary hemorrhage which is due to the maceration of the tissues by secretions, and also to the liquefaction necrosis caused by bacterial invasion. When excision or curettage following electrocoagulation is not practiced, the devitalized



Fig. 10.—Advanced basal-cell epithelioma of the nose.

Fig. 11.—Showing result of one office electrodesiccation operation under local anesthesia.

Fig. 12.—Illustrating artificial nose: sculpture method of reconstruction.


Fig. 13.—Squamous-cell epithelioma of nose, grade 3.

Fig. 14.—Result of one electrodesiccation operation under local anesthesia. Note cosmetic result.

tissue is permitted to slough naturally, and to separate by degrees. The time which elapses before separation of the slough depends upon the character of the tissue destroyed, whether dense, loosely combined, friable, or necrotic, and also upon its anatomic location. It may take but two days in some cases for the slough to separate, and in other instances it may take as long as seven days. Bone or cartilage when subjected to electrodesiccation or electrocoagulation will sequestrate in from about six weeks to two months, depending upon the intensity and quality of the current employed for its devitalization.

FIG. 15.—Basal-cell epithelioma of the nose.
FIG. 16.—After one electrodesiccation operation. Note cosmetic result.

ELECTROSURGICAL METHODS AND IRRADIATION

Since electrosurgical methods, radium, and x-rays are so frequently employed together in the same case, one method cannot be properly discussed without also considering the others. In dealing with *localized* benign or malignant lesions, the superiority of these electrosurgical methods over irradiation is shown by definite histologic changes, and by the critical comparison of clinical end-results. This may be explained by the fact that where electrosurgical methods are employed, the diseased tissue only is destroyed, and the vitality of the surrounding normal structure is conserved. Subsequent treatments by electrosurgery, should they be necessary, offer quite as good a prospect of success as though the tissues had not received previous treatment, owing to this conservation of the vitality of the adjacent tissues. On the other hand, with irradiation of such intensity as to produce a lethal effect upon the cells of malignant or other types of growths,

lated, and not through the viable tissues beyond it. If necessary, the base may then receive further electrodesiccation or electrocoagulation treatment.

Excision or curettage immediately following electrodesiccation or electrocoagulation is practiced less frequently in lesions within the mouth, or on mucous membranes elsewhere, than upon the skin surface, owing to the greater possibility of secondary hemorrhage which is due to the maceration of the tissues by secretions, and also to the liquefaction necrosis caused by bacterial invasion. When excision or curettage following electrocoagulation is not practiced, the devitalized

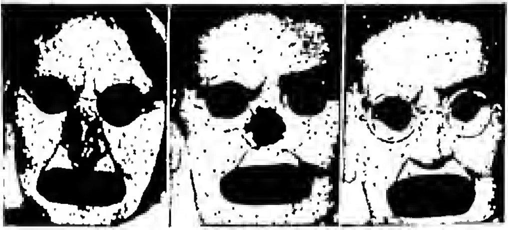

FIG. 10.—Advanced basal-cell epithelioma of the nose.

FIG. 11.—Showing result of one office electrodesiccation operation under local anesthesia.

FIG. 12.—Illustrating artificial nose: sculpture method of reconstruction.

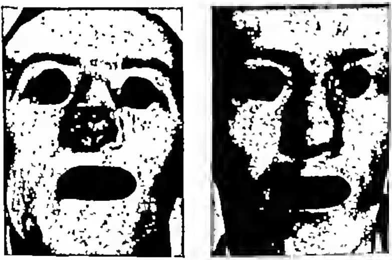

FIG. 13.—Squamous-cell epithelioma of nose, grade 3.

FIG. 14.—Result of one electrodesiccation operation under local anesthesia. Note cosmetic result.

Indications and Contraindications.—Owing to these resultant changes, irradiation should certainly not be used routinely in conjunction with electrodesiccation or electrocoagulation in distinctly localized benign or malignant lesions, with the exception of very malignant squamous-cell lesions (such as grades 3 and 4, according to Broders) when irradiation treatment in conjunction with electrosurgical methods should be considered for its lethal effect upon possible outlying malignant cells, since there is a greater likelihood of the existence of such cells and of their recurrence in this more malignant type of lesion. However, after any treatment recurrences may not always be due to incomplete primary work, but rather to entirely new lesions occurring in soil favorable to their development.

There are instances of advanced cases of malignancy in inaccessible locations in which electrodesiccation or electrocoagulation is not applicable, owing to the involvement of vital structures and to the impossibility of doing complete work. *Unless the lesion can be completely removed well beyond into the normal tissue, electrosurgical methods are, as a rule, contraindicated.* In exceptional cases a large necrotic mass of malignant tissue may be removed by electrosurgery, even though the work is known to be incomplete, to permit of the more satisfactory, immediate use of radium or x-rays. In such cases, irradiation, as the most important factor in treatment, is preferable to other alternatives. My experience has been such, however, that I feel strongly that electrosurgical methods, with the exceptions noted, should be employed alone in primary localized lesions, where it is possible to remove all the disease at one operation.

Electrodesiccation and electrocoagulation are both contraindicated, with the exception noted, in extensive lesions that cannot be destroyed in their entirety with one operation. If any of the disease is left, it will usually be stimulated to greater activity unless irradiation is immediately employed thereafter. If vital structures are involved and the case is inoperable, then irradiation treatment is preferred to electrosurgical or other methods.

In addition to removal by electrosurgical methods of primary lesions of the very malignant squamous-cell or other types of growths, it is quite important, indeed it is necessary, to treat the lymphatic drainage areas by radium or x-rays, or in some instances by a combination of both, to inhibit or destroy malignant cells migrating to the glands, or to destroy the pathologic element if true metastasis has already taken place. In some instances it is necessary to excise the involved glands, by means of either the high-frequency knife or the cold scalpel. This is especially true if the glands have broken down. Preoperative irradiation of the metastatic glands inhibits the proliferation of malignant cells; thus recurrence after removal is less to be feared. Postoperative irradiation at the site of the excised glands is also a practice to be recommended.

it is impossible to avoid lowering the vitality of the surrounding normal tissue by producing nerve, tissue, and circulatory changes. This is true, at least to a certain degree. Therefore, in case of recurrence, little more can be hoped from further irradiation treatment, owing to the decreased radio sensitivity of the tissues and also to the resultant changes before mentioned. These are facts well known to experienced radiologists and other close observers.

FIG. 17.—Squamous-cell epithelioma, grade 2, of cheek and angle of lips, extending through into the mouth.

FIG. 18.—Result of one electrocoagulation operation under ether anesthesia. Radium treatment to lymphatic drainage areas. No recurrence in six years. A plastic operation to close opening into mouth could be successfully performed.

FIG. 19.—Squamous-cell epithelioma of the lower lip, grade 3.

FIG. 20.—Result of one office electrodesiccation operation and radium treatment to neck. Note absence of contracted scar, and regeneration of normal tissue.

As before stated, electrodesiccation and electrocoagulation are adapted to the treatment of benign and malignant growths of the skin and accessible mucous membranes that are limited in extent and do not involve vital structures. These methods are therefore peculiarly adapted to the treatment of neoplasms involving cutaneous surfaces, as well as lesions occurring in accessible mucous membranes, such as are found in any part of the oral cavity and adjacent parts on the lip, jaw, nose, throat, tongue, larynx, eye, sinuses, orbit, par-

FIG. 15.—Extensive basal-cell epithelioma involving whole of upper lip, antrum, nose, septum, alveolus, and hard palate. Recurrence after excision, radium, x-ray, and serum treatment.

FIG. 16.—Result of one electrocoagulation operation. No recurrence in 15 years.

FIG. 17.—Features constructed by sculpture method and attached to spectacle frames.

otid gland, ear, etc. Likewise, they may be employed advantageously in growths of the bladder, the operator working through an operating cystoscope, or through a suprapubic opening; also growths of the vagina, urethra, uterine cervix, and the rectum may be treated by this method. Recent experience has shown that the high-frequency knife may be effectively employed for the removal of growths of the abdominal serous membranes.

Since malignant lesions of mucous membranes are prone to be more active than those occurring on the skin, the efficiency of electrodesiccation and electrocoagulation is in some instances increased by the combination of the high-frequency knife, the cold scalpel, radium and x-rays. The basal-cell type of epithelioma, occurring, for example,


Fig. 21.—Squamous-cell epithelioma of lip.
Fig. 22.—Result of one electrodesiccation operation.


Fig. 23.—Squamous-cell epithelioma, grade 4, completely involving the lower lip and alveolus.

Fig. 24.—Result of one electrodesiccation operation and radium treatment to neck.

The choice between local or general anesthesia in a given case is a matter of the personal judgment of the operator, although it might be stated that much of this work can be done under local anesthesia. It seems advisable that ether be removed from the room during electrosurgical operations, the operation being performed while the patient is coming out of ether. Dr. Mock states that he covers the ether mask with a wet flannel blanket during electrosurgical thyroid operations. He further adds, "Ethylene should never be used when electrosurgery is employed."

FIG. 29.—Squamous-cell epithelioma of floor of mouth and alveolus, grade 4.

FIG. 30.—Result of one electrodesiccation operation and radium to lymph nodes. No recurrence in 8 years.

Effects of Electrodesiccation and Electrocoagulation.—In addition to the electrodesiccation or electrocoagulation effect on the affected tissues, and to the sealing of blood and lymph channels, the heat penetrates beyond the area actually destroyed and devitalizes malignant cells for a considerable distance beyond, without permanently impairing the normal tissues, thus lessening the likelihood of local recurrence or metastasis, and conserving the maximum amount of normal tissue. It is, however, difficult or impossible to determine by any means now at our command exactly how far this heat penetrates in a given case, and the depth to which the malignant cells are destroyed.

Malignant cells, especially those that are least differentiated, are more vulnerable to heat and are devitalized at a lower degree of heat

on cutaneous surfaces, such as the face and eyelids, is of relatively low-grade malignancy, and though the lesions may be extensive both as to area and depth, even though complicated with bone involvement, they may be so effectively treated by the electrodesiccation or electrocoagulation methods that recurrences are infrequent, provided the operations are properly performed.

In localized squamous-cell epitheliomas, however, on cutaneous surfaces or mucous membranes, which are found to be more malignant in type, the results are almost but yet not quite as good as in the basal-cell lesions, the results depending to a great extent upon the grade,

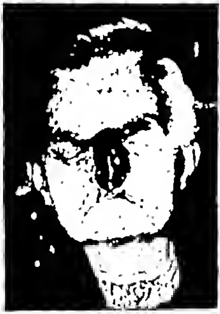

FIG. 18.—Illustrating the result of an electrocoagulation operation for removal of a very far advanced rodent ulcer involving the whole of the upper lip, nose, maxillary ethmoids, frontal sinuses, and left orbit. The dura was exposed, yet the patient recovered and lived for three years after the operation.

or in other words, upon the degree of differentiation in the cells, from the embryonic to the adult cell. This differentiation can be demonstrated by the trained pathologist. The recognition of differentiation in cells has proved a valuable guide in planning treatment. In such cases, radium or x-rays should be used locally in combination with electrodesiccation and electrocoagulation. When the cells are embryonic in character they exhibit but slight resistance to irradiation treatment. On the other hand, when differentiation has progressed they show greater resistance. Therefore, to obtain good results the dosage must be increased to overcome this resistance. When the growth is no longer localized and metastasis has occurred, it is again emphasized that other methods must also be used in addition to electrosurgical methods.

ated cells is also well established. This property of heat penetration should not, however, influence the operator to do incomplete work, for it cannot be relied upon entirely in all instances to destroy deeply located malignant cells. It is safer to err on the safe side by performing radical operations when one has to deal with malignancy. The sealing of blood and lymph channels and the prevention of dissemination of malignant cells should be an advantage, and might conceivably aid in preventing local recurrence and metastasis. The frequent immediate relief from pain after operation is worthy of note. There is no field of surgical specialization in which electrosurgical methods cannot be employed to advantage in some cases.

FIG. 34—Illustrating a case of epulis. Electrodesiccation is a successful method of treatment, conserving the maximum of normal structure

Apparatus and Operator.—High-frequency apparatus, as devised by different manufacturers, vary greatly in construction, hence there is a corresponding variation in the quality of the currents produced. The thermic intensity may be too great or too little, and an undesirable faradic effect producing shock and contraction of the tissues is to be expected when the improperly constructed machines are used. This lack of standardization is unfortunate, since in order to produce the electrodesiccation and electrocoagulation effects under ideal conditions an accurate balance must be obtained between the voltage and the amperage, and also between the capacity, inductance, and resistance. Thus, different operators employing various types of apparatus may obtain different results. Indifferent results can be obtained, or, indeed, irreparable damage can be done by an operator not possessing practical knowledge of the various factors involved. This notation seems appropriate and most important, since a considerable number of cases have come under observation that have been improperly treated by electrodesiccation and electrocoagulation; thus an errone-

than are normal cells. This seems to have been demonstrated by the experimental work of Doyen and others and it has been borne out by my own practical experience. The thermic sensitiveness of these cells to the action of the high-frequency current has often been observed clinically and demonstrated histologically. Likewise, the greater sensitivity to radium and x-rays of embryonic cells than of well-differenti-

FIG. 31.—Showing typical result of one electrocoagulation operation for extensive squamous-cell carcinoma of antrum, hard palate, and alveolus.

FIG. 32.—Showing properly fitting denture to fill up space, insuring improved speech, mastication, and greater cleanliness.

FIG. 33.—Illustrating a case in which an electrocoagulation operation was performed to remove extensive carcinoma of the antrum after surgical exposure through an external opening. The hard palate and alveolus were not involved with disease.

ous impression has been made on the minds of those seeking authentic knowledge concerning the methods. Moreover, electrosurgical methods can be practiced with a maximum degree of satisfaction only by those who have had ample surgical training and experience. These methods should not be considered as something distinct and apart, or as a specialization, but rather as a valuable adjunct to the surgeon trained in surgical judgment and technic, and with sufficient operative experience.

General Technical Considerations.—There are many variations in the technic of electrodesiccation and electrocoagulation to meet various indications. The technic cannot be completely described; it

Fig. 39.—Showing a case of adamantinoma, associated, as is usual, with bone cysts. Electrocoagulation is a successful method of treatment.

must be learned by studying the technic of a capable operator and then further perfected by practice upon raw meat and laboratory animals before human subjects are treated. I desire to impress the fact that the technic of electrodesiccation and electrocoagulation is not simple, nor should the work be undertaken lightly. Much good can be done by using them judiciously, and perhaps considerable damage can result from their improper use, even in the hands of otherwise accomplished surgeons. Thorough preparation should therefore be made before engaging in what might possibly be a hazardous procedure. While those who employ electrosurgical methods judiciously have reason to be enthusiastic, they should not grow so enthusiastic as not to realize the limitations of these methods, for they do have limitations. The cold scalpel, hemostats, and sutures cannot by any means be discarded from use in general surgery.

FIG. 35.—Showing result of a radical electrocoagulation operation for extensive carcinoma involving alveolus, hard palate, and antrum on both sides.

FIG. 36.—Showing deformity in natural position after operation.

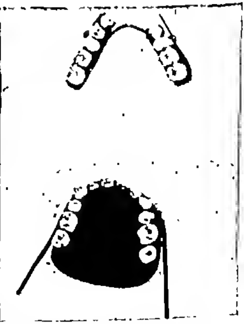

FIG. 37.—Natural appearance after the use of a properly fitting denture.

FIG. 38.—Showing upper and lower dental plates used in this case.

Each case should be regarded as a law unto itself, and after full advantage has been taken of our superior present-day laboratory and other facilities, should be studied, intelligently and judicially, before a decision regarding the proper method, or combination of methods, is reached in a given case.

Group Practice.—Since it is well-nigh impossible for one man to become thoroughly proficient in the expert application of all measures hitherto mentioned, group practice is perhaps the best solution of the difficulty. If one is not in a position to employ all recognized methods and adjuncts, either by oneself or in group practice, one should not attempt to treat cancer, except, perhaps, in selected cases.

FIG. 43.—Leukoplakia of the tongue. Electrodesiccation is the most satisfactory treatment for this lesion on any accessible mucous membrane

Hemorrhage.—When electrodesiccation or electrocoagulation is correctly employed, hemorrhage during, or immediately after, the operation is not likely to occur. Secondary hemorrhage may possibly occur several days later at the time of separation of the slough, when the larger vessels have been electrodesiccated or electrocoagulated through. Usually, however, organization has taken place by the time the slough separates and the terminal ends of the vessels have thrombosed, thus preventing hemorrhage. This, however, cannot always be depended upon. This risk, when such a possibility appears to exist, should be obviated by preliminary ligation of the involved blood vessels, if it is practical to do so in a given case. This is especially true when the electrodesiccation or electrocoagulation method is employed, in which case sutures are not used and the wounds must heal by granulation. When the high-frequency knife is employed, the larger

Operators should therefore be trained to know when other methods are indicated in preference to electrosurgical methods, and also when other methods should be used in conjunction with them. Contrariwise they should not employ cold scalpel surgery when electrosurgical methods can be employed to better advantage. We should not lose sight of the respective value of the cold scalpel, the high-frequency knife, radium, and x-rays, especially in cancer work, each having a place in modern practice. Electrosurgical methods cannot be practiced to full advantage without according to the other methods full and equal consideration. Electrosurgery is but one, though a valuable, unit in the progressive surgeon's armamentarium.

FIG. 40.—Extensive squamous-cell epithelioma of tongue and floor of mouth, grade 2.

FIG. 41.—Appearance after amputation of tongue by the electrocoagulation method and radium treatment to lymphatic drainage areas in neck.

FIG. 42.—Showing artificial tongue made of cotton, thus materially improving speech.

of the high-frequency knife. Some surgeons of experience who have weighed both methods in the balance prefer the latter method.

May I stress the important fact that the use of the electrodesiccation or electrocoagulation method of treatment will frequently reclaim cancer cases that would have been quite hopeless were these methods not available.

Histologic Studies.—The microscopic picture of neoplastic tissue submitted to electrodesiccation presents typical characteristics. While the cells still retain their outline, they appear shrunken, elongated, and dried up. Evidence of such degenerative changes as hydropic or fatty degeneration is not discernible. The blood vessels in the immediate and adjacent field of operation are thrombosed.

FIG. 45.—Illustrating a case of advanced squamous-cell carcinoma, extending through the cheek, also involving the alveolus, floor of mouth, and tongue, with metastasis to the cervical glands. Much of the cheek and diseased parts in other locations removed by electrocoagulation, lower jaw resected, and radium used interstitially in the glands. After a year without recurrence, a plastic operation was performed, utilizing a flap from the chest. No recurrence in 15 years.

In tissue subject to coagulation there is complete loss of cell outline. The neoplastic cell element seems to have fused into a structureless homogeneous mass, with a resulting hyalinized appearance. The blood and lymph channels are thrombosed. The secondary and associated changes in all such lesions are degeneration and fibrosis. Whether the fibrous and connective tissue shall be abundant and dense, or less abundant and soft, is influenced by the amount and nature of the accompanying degenerative and necrotic material, which in turn are determined by the particular type of irritant. Thus, after electrodesiccation the fibrosis is slight, and the resulting scar is soft and pliable. Following electrocoagulation the fibrosis will be more or less abundant, the amount depending on the intensity of the heat generated and the consequent degree of frame destruction.

vessels should always be ligated and the incision closed by proper suturing; the wounds are then expected to heal by first intention. Disappointment in this has, however, sometimes occurred, depending for the most part upon the dexterity and the experience of the operator in the use of a new method and instruments.

Gastrostomy and Colostomy.—In cases of mouth and throat malignancy, when a patient's vitality is low and he is undernourished owing to his inability to ingest the proper amount and quality of food,

FIG. 44.—Illustration of exostosis of hard palate, which sometimes should be removed to make possible a properly fitting denture, and for other reasons. Electrodesiccation is ideal for the removal of this lesion and the danger of breaking through into the antrum is minimized.

and when tube feeding through the nasal passage is impractical, a preliminary gastrostomy should be performed and the patient fed through a tube until in proper physical condition to withstand the proposed operation. It is noteworthy how some patients improve physically after resorting to the rational expediency of gastrostomy. A gastrostomy can readily be done under local anesthesia, and the opening in the stomach can be closed after it has served its useful purpose. It is likewise prudent in the majority of instances to perform a colostomy before attempting treatment of cancer of the rectum.

There are numerous other circumstances frequently met wherein the combination of the cold scalpel and some form of electrosurgery can be employed to advantage. Such operations as gastrostomy and colostomy may be performed either by the cold scalpel or by means

shorter operations, the decrease in trauma, and the greater possibility of sterilization are the chief advantages of the method.

At a conference on electrosurgery during the meeting of the American College of Physicians in Philadelphia, October, 1930, Dr. Howard A. Kelly spoke upon the subject of electrosurgery in part as follows:

In brief summary, some of the conditions with which we deal are:

Various malignancies about face, lips, mouth, tongue, fauces.

For carbuncles it renders signal services in exsecting the diseased area, leaving a clean, sound, aseptic, rapidly healing wound; in fact, it undoubtedly

Fig. 47.—Squamous-cell carcinoma of parotid gland, ear, and lower jaw, with infiltration into neck.

Fig. 48.—Result of combined electrocoagulation, radium treatment, and resection of lower jaw. Patient is living without recurrence after 10 years, though with facial paralysis.

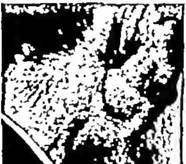

Fig. 49.—Squamous-cell epithelioma involving the parotid gland and other tissues.

Fig. 50.—Showing result of one office electrodesiccation operation under local anesthesia. Facial nerve not injured; no recurrence in 16 years; patient still living.

Conclusions Regarding Electrodesiccation, Electrocoagulation, and Combined Methods.—Electrodesiccation and electrocoagulation when employed with correct technic are perhaps the most satisfactory methods yet designed for the treatment of localized neoplastic and allied lesions of the skin and mucous membranes. The cold scalpel, the high-frequency knife, radium, and x-ray are also valuable and indispensable in their respective rôles, and in some instances they may be used advantageously in combination with electrodesiccation and electrocoagulation, each method complementing the other.

FIG. 46.—Illustrating line of excision to expose malignant disease of the upper jaw, anterior nares antrum, floor of orbit and buccal surface preliminary to treatment by electrocoagulation.

HIGH-FREQUENCY KNIFE

Owing to the flexibility of the high-frequency currents, it is possible so to regulate the capacity, inductance, and resistance, with variable degrees of damping, as to permit cutting through the tissues with a suitable electrode quite as accurately and as cleanly as by the cold bistoury; moreover, the wounds will heal by first intention. I had the opportunity of experimenting with, and reporting to the manufacturers upon, one of the first practical machines and instruments designed for this work about one year before it was adopted for practical use. Dr. George A. Wyeth, of New York City, following up these studies, first called the attention of the medical profession to the perfected cutting current in a paper read before the Surgical Section of the New York State Medical Society in Rochester, N. Y., April, 1924. Schmidt, Kelly, Ward, Cushing, Mock, Trowbridge, and others later contributed toward the development of this method. Surgeons throughout the world are now widely employing it in major surgery, including abdominal, intestinal, thyroid, gynecologic, genito-urinary, nose and throat, eye, ear, and brain surgery, especially in the case of neopla- [illegible] diseases. The minimized primary hemorrhage, the

sulating tissues by coagulation. In the spinal cord it is easy to prognosticate a use in all lesions where it is simply necessary to divide a nerve trunk or to destroy benign or malignant growths *in situ* without the usual protracted manipulations for exposure and removal with the attendant traumatisms.

In all these operations, it is advisable to maintain the careful technic of the operating room in major and minor surgery. This should be done for our own sakes and in no wise to impress the patient. How far we may safely modify our stringent technic will appear only after considerable experience.

In closing, I feel profoundly thankful that our honorable society, composed as it is of our leading surgeons, is seriously taking this matter in hand. Personally, I give thanks for such a new and potent adjuvant, which simplifies our technic, speeds the operation, does many things better, and some things heretofore impossible, while it greatly lessens pain and the liability to subsequent infections. [*Surg. Gynec. Obst.*, p. 503 (Feb. 15) 1931.]

Dr. Oscar E. Nadeau, Chicago, Ill., summarizes his experience as follows: "The electrosurgical unit in its present state of development is a distinct advantage in modern surgical technic. New indications are found every day. It is a new method, the details of which must be thoroughly familiar, not only to the surgeon, but to the entire staff of assistants and nurses." [*Surg. Gynec. Obst.*, p. 511 (Feb.) 1931.]

Dr. Howard Lillienthal, of New York City, at the conference mentioned drew from his experience the following conclusions:

1. The electric method under discussion promises to be a great aid in general surgery.
2. The tendency to wound infection is greatly reduced.
3. Hemostasis is quick and sure. In my small series of cases there has been no secondary bleeding.
4. Healing has been normal in rate and in firmness. The time is too short to form conclusions as to keloid. Thus far I have not observed this condition.
5. When local anesthetics were employed, my impression is that there may have been electric subjective reactions of pain, and that the pain or discomfort was more than when the scalpel was used. On dividing muscle, there has been more twitching than is ordinarily seen on knife section. (Twitching is caused by faradism due to improper windings in apparatus.—W. L. Clark.)
6. The apparatus must be properly managed. Its liability to get out of order, or to diminution in functioning power, may have to be considered. Thus far I have not noted deterioration of this kind. It seems to me that the electric method is extremely valuable in general surgery, and that the wounds are more likely to be aseptic than those in which the scalpel is used.

In this discussion I have not dealt with the technical part of electrosurgery. There is danger of producing accidental burns by contact of the electrode with metallic bodies in the wound, such as metal retractors or artery clamps. I believe that the principal use of the new method in general surgery will be for making incisions in the soft parts, including the skin, and of course, in the removal of lesions outside the body cavity. The action of the electrode on the tissues seems to be that of intense heat, but the intensity is so great that with the cutting motion there is rapid

replaces the actual cautery which has been growing in favor, and is infinitely superior to the wretched poulticings.

No method outside of the wonderfully effective services of radium is worth considering in dealing with malignant tumors of the scalp.

In malignancy of the skin in all parts of the body, electrosurgery is second only to radium; it supersedes radium in nevi. Often when the use either of the x-ray or radium has been overdone and there still remains a sclerosed or an extensively ulcerated mass, nothing approaches the efficiency of the exections of electrosurgery.

Epitheliomas of the dorsum of hand or wrist, even when the growths extend into the tendons, are admirably handled by electrosurgery, which is secondary only to radium well-managed.

For certain breast cases it is supreme, especially in the presence of nodular, ulcerated, massive scirrhous breasts, when there is not a shadow of a hope of a successful removal by classic methods. In such case electrosurgical extirpation of the mass often proves of inestimable value in stopping the pain and the discharges, as well as in freeing the poor victim of the unsightly reminder of a doom daily approaching. Nor need one always hesitate even when there is fixation of one or more massive glands. After the main mass is removed, areas of lingering disease can often be coagulated out of existence and glands can be removed, or, with the fire of the heavy flashing current, destroyed *in situ* and left to be absorbed. Some patients in this group express more gratitude for relief than others do for a radical cure. In many instances recurrences are slow to occur and when the patient is old, it becomes a special blessing, as she may go to the end apparently cured.

Malignancies about the abdomen offer a fertile field for electrosurgery. We can destroy papillomatous ovarian implants faster than it can be stated. Small areas of carcinoma are readily destroyed and left where found, while a scirrhous nodule in the intestinal tract can be widely destroyed even through into the lumen of the bowel, and abandoned after turning it in and suturing the wound with a couple of Lembert sutures. In resecting the bowel for malignancy, if one finds an affected gland in the fork of a large mesenteric vessel distant from the field of operation, it can be wiped out of existence by puncturing it and coagulating the whole gland, if needs be, by grasping the vessels with the fingers to limit the transmission of the heat.

Malignant vulvar disease should always be removed by electrosurgery and any inguinal glands sparked out of existence.

In experiments on the liver and kidney, Ward and Pearse have resected portions of both organs with a marked lessening of the hemorrhage. In the liver there was practically no bleeding during excision of a complete lobe. In nephrotomy and partial nephrectomy, in spite of the large arterial supply of the kidney, bleeding was markedly diminished in the peripheral areas. In the neighborhood of the pelvis, the larger vessels required clamping and coagulation. Scott has carried this into the clinical field, removing portions of the kidney for tumors and stone.

Electrosurgery is opening up a large field in brain work as it will in spinal cord surgery. In the brain, as shown by Cushing, electrosurgery is of the greatest value in opening up the meninges, in making a safe passage to an abscess, and above all in the effective handling of hemorrhage. It also enlarges the field of control over malignancy, simplifying the removal of the disease in sterilized "curls" and in the further treatment of the encap-

tends, perhaps, to prolong solid union. This is, of course, not necessarily the fault of the electric technic, for slow healing in fat subjects is never surprising. Broad approximation of wound surfaces and an interval of a day or two longer before removing sutures are advised.

The electric scalpel cuts so keenly and with so little pressure on the tissues that great care must be taken not to go deeper than is intended. For example, in dividing the abdominal wall the peritoneum should be entered in the usual way with knife or scissors for fear of injuring the viscera by the current. In the region of large vessels or of important nerves, the greatest delicacy of manipulation must be observed.

Fig. 53.—Large round-cell sarcoma involving face, antrum, malar bone, floor of orbit, and ethmoid sinuses, as well as tissues within the orbit.

Fig. 54.—Showing result of one radical electrocoagulation operation including exenteration of orbit. (No other method could possibly have produced such a result.)

The outstanding features of electrosurgery are the saving of time, the greater assurance of asepsis, and the reduction of what may be called the massage effect, so dangerous in operating through infected or neoplastic structures. [*Surg. Gynec. Obst.*, p. 513 (Feb.) 1931.]

Dr. Edward L. Keyes, of New York City, spoke conservatively, though in the main favorably, of electrosurgical methods for certain operations in the genito-urinary field.

Dr. John D. Ellis, of Chicago, in his paper, "The Healing of Electrosurgical Knife Wounds," summarizes as follows:

1. Only 60 per cent of electrocutting skin wounds in dogs where the minimum of current was used healed by primary intention, as compared to 97.5 per cent of scalpel wounds.

2. This 60 per cent which healed did not present a tensile strength equal to the scalpel wounds for 21 days.

linear disintegration of tissue with minimum charring or coagulation. A cautery blade of the ordinary type loses its heat by contact with the tissues, so that coagulation is more massive and the knife sticks to the surface of the wound. With the electric scalpel, on the contrary, the wound is clean cut, and except for the absence of bleeding, its edges in skin incisions resemble those made with the sharp knife.

Skin, fat, and muscle are divided without apparent effort by the operator, and denser structures such as fibrous tissue may also be sectioned, but more slowly. Capillary oozing is practically absent. With the rapid current which I have used in my operations, there is bleeding from many

FIG. 51.—Extensive basal-cell epithelioma of the rodent ulcer type, involving the abdomen, two ribs, and at one point extending almost through to the peritoneum.

FIG. 52.—Result of one electrocoagulation operation under ether anesthesia. No recurrence in 6 years. No other method but electrocoagulation could have accomplished such a good result.

of the smaller as well as the larger vessels when they are divided, but this depends, of course, on other things than the mere division of the vessel, e. g., the coagulability of the blood and the elasticity of the vascular walls, as well as the hydrostatic pressure in their lumen. All bleeding points are caught with forceps. Whether a vessel needs to be ligated, or whether it may be permanently sealed by touching the clamp with the coagulating electrode, can be determined only by experience. . . . As a rule, however, a small spurting vessel which has been sealed should not bleed on lightly sponging the wound. If there is any doubt, ligation should be done as in ordinary surgical procedure. In any event, I believe it is safest to deal individually with wounds of the vessels. Secondary hemorrhage in the absence of suppuration is no more likely to occur after an electrically made wound than after an incised one. I confess to insufficient experience to generalize too certainly in this matter, although in some of my cases the wounds have been very extensive. *When there has been neat approximation, primary union may be confidently expected.* I feel, however, that in the electrically produced wound the presence of a thick adipose layer

1. *Rapid and complete severance of the tissues, whether for removal* or simple incision through normal or abnormal structures. The rate of speed in handling the electrode, together with the power control, governs the degree of dehydration and the electrocoagulation of the severed surfaces, and hence controls or checks the bleeding or oozing from capillaries and also seals the lymph vessels, thus giving a clear operative field. Such a clear operative field favors an easier and quicker operative technic, together with the elimination of the obstructive hemostatic forceps and the constant and bothersome use of gauze sponging, thus reducing the time limit of an operation—major or minor—to a minimum. While the smaller blood vessels are thus controlled by the dehydration of the cutting electrode, the larger vessels should invariably be ligated as a procedure of safety.

FIG. 57.—Basal-cell epithelioma involving upper and lower eyelids, canthus, and conjunctiva.

FIG. 58.—Showing a typical result of the electrodesiccation removal of such lesions. I have personally treated over 900 cases of epithelioma of the eyelids and canthi, and my experience indicates the great value of the electrodesiccation method in these lesions.

2. The facility of using the electrosurgical knife is acquired only by *thorough* study of the manipulation, and *strict* attention to the principles governing the use of the same upon living tissues of the human body after multifold experimentation upon a nonviable subject.

In so using the electrosurgical knife, it has been the custom of the writer to entrust the management of the foot switch—which lets on or releases the current—to the trained assistant operating nurse, who at the announcement of "on" or "off" controls the current. This feature cannot be emphasized too strongly, inasmuch as the operator should give his sole attention to the technic of the operation and not be disconcerted by the use of either foot on the switch; then, too, the operator can then be free to change his position as the exigencies of the operation demand.

A novice should never be allowed to use the electrosurgical knife on the living human body, nor should any surgeon attempt to use it without previous close study of its applicability and manipulation.

3. Incisions of the stomach and muscle with the electric knife present a much more satisfactory percentage of union and strength of cicatrization comparable to the wounds with the scalpel, except that the electrocutting wounds of the stomach were notably weaker at the midpoint of healing.

Dr. A. C. Scott, Temple, Texas, in his paper, "Electrosurgery in the Treatment of Malignant Disease," stated, "Observation in the use of the loop cautery knife in more than 1,500 operations for malignancy leaves us with no other alternative than the conclusion that at present it is the safest and most dependable means of eliminating local recurrence of malignancy after major surgical removal."

FIG. 55.—Extensive basal-cell epithelioma involving the eye, all tissues in the orbit, bone, nose, and tissues surrounding the orbit.

FIG. 56.—Result of removal of diseased tissue, including complete exenteration of orbit by the coagulation method.

Other papers by Dr. H. F. Pierce, Ph. D., Baltimore, Md., Dr. A. L. MacLean, Baltimore, Md., and Dr. Bowman C. Crowell, Chicago, Ill., commented favorably upon the possibilities of the high-frequency knife in general surgery.

The following has been contributed by Dr. Edward H. Trowbridge, A.M., M.D., F.A.C.S., of Worcester, Mass.:

In the employment of any special instrument or apparatus in surgery, certain prerequisites are obvious.

A. General applicability.

During the past three years the electrosurgical knife has been used in all operative cases in the Harvard Private Hospital, Worcester, Mass., whether major or minor in character, such as incisions through the abdominal wall, cholecystectomy, appendectomy, cystotomy, abdominal hysterectomy (supravaginal and complete), cesarean section, amputation of cervix.

B. The various features of the electrosurgical knife are as follows:

ceps, which would obscure the field and retard the progress of the operation, was eliminated, and a more rapid operation performed, as time was an important element. The writer is an ardent advocate of the electrosurgical knife.

Neoplasms of Face, Nose, Eyelids, Ears, and Cutaneous Surfaces Generally

Neoplasms of the face, nose, eyelids, ears, etc., whether benign or malignant, require a method which will insure a good cosmetic result, without sacrificing thoroughness of removal. Unless the lesion is very



Fig. 61.—Melanotic sarcoma involving the orbit, ethmoidal and frontal sinuses.
Fig. 62.—Result of one electrocoagulation operation.
Fig. 63.—Showing artificial eye and brow by the sculpture method.


Fig. 64.—Mixed-cell sarcoma originating in the ethmoid sinus, filling the orbit, and causing great bulging of the eyeball.

Fig. 65.—Result of a radical coagulation operation and radium treatment. Photograph taken four years after the operation.

The advantages in the use of such an electrosurgical knife are readily comprehended as when employed in the removal of the gallbladder, and likewise in pelvic surgery, where the structures to be removed are so deeply situated, and, at times, so difficult to manipulate.

3. The healing of the tissues.

Primary healing is invariably obtained, and the ideal line of union is the pleasing result. This result, however, may not be achieved if the tissues be subjected to a too extensive dehydration of the cut surfaces, and a slight or somewhat enlarged slough be caused, and healing be thus retarded. Such a condition did occur in the experience of the writer in doing a cystotomy for the removal of two large calculi on a person with thick abdominal wall. This case was among those first operated upon with the use of the knife, but no such experience has occurred since that time.

FIG. 59.—Showing a recurrence after surgical excision of a small round-cell sarcoma of the lower eyelid.

FIG. 60.—Again illustrating the result of one electrodesiccation operation without cicatricial contracture, and regeneration of normal tissue. Patient can close eyelids, and vision is not impaired. This case was followed for eight years and no recurrence was observed.

4. After-results. Very little or no opiate at all is required postoperatively. Drainage in less amount—drainage tube removed within shorter interval (two to four days).

Case of complete hysterectomy on January 2, 1932, age 70, operation refused for over two years; relief demanded by patient. The electrosurgical knife used in opening the abdomen and in severing the broad and round ligaments and in severing the cervix from the vaginal junction; a boggy uterus, size of grapefruit exposed with two fibroids size of English walnut on either side of uterus just above cervix. The uterus was so rotten at the cervical junction that the tissues were easily torn when traction was made, and hence the necessity of removing the uterus as in supravaginal technic and then the cervix subsequently.

In all this procedure the minimum amount of blood was lost; such a favorable resul however, could not have been possible had the ordinary scalpel been used. Then, too, the necessity of using several hemostatic for-

ceps, which would obscure the field and retard the progress of the operation, was eliminated, and a more rapid operation performed, as time was an important element. The writer is an ardent advocate of the electrosurgical knife.

Neoplasms of Face, Nose, Eyelids, Ears, and Cutaneous Surfaces Generally

Neoplasms of the face, nose, eyelids, ears, etc., whether benign or malignant, require a method which will insure a good cosmetic result, without sacrificing thoroughness of removal. Unless the lesion is very



Fig. 61.—Melanotic sarcoma involving the orbit, ethmoidal and frontal sinuses.
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Fig. 64.—Mixed-cell sarcoma originating in the ethmoid sinus, filling the orbit, and causing great bulging of the eyeball.

Fig. 65.—Result of a radical coagulation operation and radium treatment. Photograph taken four years after the operation.

extensive, the electrodesiccation method admirably fulfils these requirements. Given a case of epithelioma of moderate size on the face or other locations mentioned, requiring complete removal, the technic of an electrodesiccation operation is briefly described as follows:

Technic.—The patient should lie in a convenient position on an operating table. Preliminary cleansing and sterilization of the operative field is first practiced as in any surgical operation. Novocaine (1 per cent) anesthesia by infiltration well beyond the lesion has been found

Fig. 66.—Congenital cavernous angioma of the orbit.

Fig. 67.—Showing complete exenteration of the orbit by coagulation. Eyelid was divided and dissected back so as not to be injured by the current.

Fig. 68.—Lids after suturing, before patient came out of ether.

Fig. 69.—Ultimate result, with conservation of eyelids. An artificial eye is under consideration.

to be quite satisfactory. After the current is regulated to the proper intensity as hitherto described, it is passed through a sharp sewing needle, held in a suitable handle, of which there are several types available for the purpose on the market. Owing to the relatively high voltage of the current producing the electrodesiccation, it is not necessary to employ an indifferent electrode anywhere on the patient's body to complete the circuit. The current is carried to the ground, thus sufficiently completing the circuit through the patient's body.

The growth is then electrodesiccated through its area and depth (according to the general technic described under the heading

FIG. 70.—Glioma of the retina. Recurrence after regular surgical removal. In five weeks it had recurred and progressed so rapidly that the growth measured 25 inches in circumference.

FIG. 71.—The outside lesion as well as the disease in the orbit was removed by the electrocoagulation method. No recurrence in 9 months, when the child died of another disease, the character of which was not determined.

ELECTRODESICCATION), after first systematically cutting off the blood supply with the current in the normal tissues well beyond the disease, if it be malignant. This preliminary practice is designated by Kelly as "circumvallation." After the lesion has been thoroughly devitalized, it may be curetted away if soft and friable, or excised by scissors, cold scalpel or the high-frequency knife if dense and firm. The cutting, however, should be done through the electrodesiccated tissue if possible, and not beyond it into the healthy tissue. There should be no primary hemorrhage, and indeed, no secondary hemorrhage, unless a fairly large vessel has been electrodesiccated through. Precautions should be observed to obviate this possibility as hitherto described. The wound is dressed according to classical surgical rules, the remain-

ing slough is removed when separation takes place, and healing may be expected to progress rapidly. The curative and cosmetic results in a great variety of neoplastic lesions on the face and adjacent parts are superior to other methods designed for the purpose.

Neoplasms of Lips, Oral Cavity, Jaws, Orbit, and Sinuses

Electrodesiccation and electrocoagulation are adapted for minor operations and also for the radical removal of benign and malignant growths in these locations. The advantages of these methods, accord-

Fig. 71.—Showing a case of squamous-cell carcinoma of the vocal cords, treated by electrodesiccation by direct vision through a laryngotomy opening. Radium treatment was also given from the outside. No recurrence in 10 years. A similar result was obtained in two other such cases.

ing to my experience, are the comparative freedom from hemorrhage in otherwise sanguinary operations, the conservation of the maximum amount of tissue, the ease of devitalization and removal of bone even when the involvement is extensive, the immediate relief from pain (which in these cases is often excessive), the absence of contracted scars, and the conservation of vitality in adjacent normal tissues. In case of recurrence another operation can be performed with as good a chance of success as before the first operation. This is not true of radium or x-ray treatment, for once treatment to saturation is accomplished, nothing more can be expected from their use at any future time. Even after radium or x-rays have been employed to the limit without success, or after recurrence following their use, electrodesiccation or electrocoagulation may still be used with a fair chance of success. With increased personal experience with all surgical and irradiation methods I am impressed with the inferiority of the older surgical methods for the removal of neoplasms in the locations under

discussion, and the superiority of the electrosurgical methods in these locations. I am also led to the firm conclusion that radium should not be employed in intensive doses near bone, since radium necrosis of the bone is almost certain to occur sooner or later, and that condition is almost as serious to the patient as the malignant lesion for which it was employed. For example, in the light of present knowledge it is a most reprehensible practice to apply radium in the maxillary sinuses. It may be employed from the outside, however, with comparative

FIG. 73.—Mixed-cell sarcoma of bulbar conjunctiva and cornea.

FIG. 74.—Result of one electrodesiccation treatment, with no perceptible scar and no impairment of vision. This case illustrates the practicability of treating growths near the cornea. Many such lesions have been successfully treated.

safety, since the advantage of distance is obtained, and filtration of softer destructive rays is then possible. Radium or x-ray treatment to the lymphatic drainage areas is a different matter, and the use of one or the other should be the routine practice. I am strong in the belief that all primary lesions in the locations mentioned should be removed by one or the other of the electrosurgical methods, for reasons that are so valid that possible arguments against such practice can easily be answered.

When it is considered that the mandible (from the median line to, and including, the maxillary mandibular joint) can be resected, half of the upper jaw removed, the tissues in the maxillary sinus and the bony structures enclosing it ablated, the orbit exenterated, and the frontal and ethmoid sinus cleared of disease without serious hemorrhage or great surgical shock, by a single electrocoagulation operation, then an idea is given of its potency and range.

If enthusiasm there be, it is pardonable upon the basis of facts and matured appraisement. One who has seen the curative and cosmetic effects of an electrodesiccation operation upon epithelioma of the lower lip, for example, would not again seriously consider excising it by the older surgical method.

FIG. 75.—Basal-cell epithelioma involving the ear, parotid gland, surrounding tissues, the mastoid bone, and the ear canal, extending almost down to the tympanum.

FIG. 76.—Demonstrating the fine control by the electrodesiccation method. One such operation was performed under ether anesthesia. Both facial nerve and hearing were conserved. Note cotton in ear canal for cleanliness and protection.

FIG. 77.—Squamous-cell carcinoma, grade 3, of ear and mastoid region, including involvement of bone.

FIG. 78.—Result of combined electrocoagulation and radium treatment. No recurrence in 14 years; patient still living.

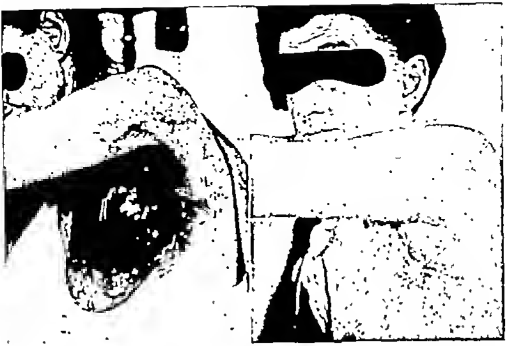

FIG. 79.—Inoperable adenocarcinoma of the breast and axilla, with extensive metastasis to the lungs and mediastinum. Too extensive to be treated by electrocoagulation, which was contraindicated because it would have been impossible to treat all the disease with safety to patient. Radium needles and deep x-ray therapy were employed.

FIG. 80.—The remarkable result shown was obtained. This patient lived 3½ years following treatment, and finally died from further metastasis. This case is shown to stress the fact that electrosurgery has limitations.

FIG. 81.—An extensive scirrhous carcinoma of breast, with deep adhesions, but without metastasis. A type of breast carcinoma in which a good result might be obtained by an electrocoagulation operation.

Technic.—As another example of technic, a description of amputation of the tongue for advanced cancer by the electrocoagulation method has been selected, and it is as follows:

If the case is far advanced with considerable emaciation, it is proper to do a preliminary gastrostomy. This has several advantages, namely, it permits of the building up of the patient's strength,

FIG. 81.—Showing typical x-ray lesion on hand of pioneer worker. Lesion on hand is squamous-cell epithelioma. The electrodesiccation method has proved satisfactory for treatment of many similar lesions.

relieves the pain incident to swallowing, and frequently results in a considerable reduction of the swelling and induration in the tongue and pharynx, following the rest given to those parts. The tongue can then be readily electrocoagulated through its base and excised. Primary and secondary hemorrhages are unusual. To diminish even the small risk, it is wise to do a preliminary ligation of both external carotid arteries. Ether anesthesia is employed; the ether should be removed from the room and the fumes fanned away when the patient is fully anesthetized and before applying the current, else the vapor might ignite. Should the operation be unusually prolonged, and should the

patient show signs of regaining consciousness, it may be temporarily discontinued as often as required while ether is again administered. Frequently the operation is of such short duration that the use of ether a second time is not necessary. Scopolamine, 1/100 grain, and morphine, 1/4 grain, may, in some instances, be used hypodermically one hour before the administration of ether. Less ether will then be necessary, and the immediate postoperative discomfort will thus be minimized.

Since electrocoagulation is produced by a current of relatively high amperage and low voltage, an indifferent electrode placed on some part of the patient's body is necessary to complete the circuit. This

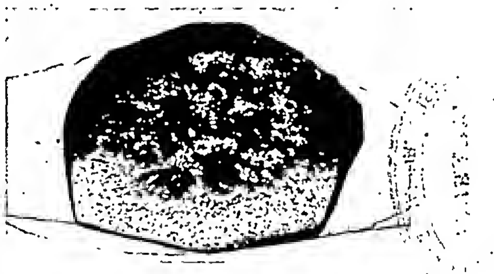

FIG. 83.—Showing squamous-cell epithelioma in skin of abdomen, a late result of x-ray treatment for a fibroid tumor of the uterus. This was before the days when dosage, character of rays, and filtration were well understood. A coagulation operation cured this patient, and complete healing was accomplished without skin grafting.

electrode may be made of block tin or some other flexible metal, or a moistened electrode, made, for example, of asbestos or heavy towels, which is in turn covered with some metal. These electrodes should measure about 8 x 10 inches, more or less, depending upon the size of the patient. The indifferent electrode selected should be placed low down on the back of the patient, the weight of the body holding it in place and insuring a good contact. A good contact at all points is important, else sparking to the body might cause a localized high-frequency burn.

After separating the jaws with a mouth gag, a heavy silk suture is passed through the tip of the tongue from side to side, by means of which the organ is drawn well forward. The coagulation needle is then brought in contact with the dorsal surface of the tongue as far back as is necessary, and the current turned on either by the operator

by means of a foot control, or by an assistant on signal. The needle is slowly moved across the tongue, and after the surface is coagulated, the needle is carefully inserted into the tongue to the proper depth at different points, allowing electrocoagulation to take place as the needle penetrates. This having been thoroughly accomplished, the tip of the tongue is elevated by means of the attached suture, and a straight sharp sewing needle of proper length is substituted for the curved needle previously used. The frenum is then coagulated, and the electrified needle is inserted between the tongue and the floor of the

FIG. 84.—Small round-cell sarcoma involving tissue of the forehead and frontal bone, and extending through into the frontal sinus and upper and lower eyelids of both eyes. *Vision lost through mechanical closure of lids.*

FIG. 85.—Electrocoagulation not indicated owing to involvement of such structures as would result in loss of vision. Radium needle treatment employed with excellent result. Showing appearance three weeks after treatment.

FIG. 86.—Showing final result. Patient lived three and one-half years after treatment, and finally died from extension of disease to the brain.

mouth. When electrocoagulation is again completed, curved scissors may be used to cut through the electrocoagulated area on both surfaces, and the tongue is then separated from its attachments and removed.

After-Treatment.—The after-treatment consists of simple antiseptic mouth washes, and the application two or three times daily of a weak solution of hyposulphite of sodium, which sterilizes, deodorizes, and tends to keep the slough free from maceration. Care should be taken not to remove the slough prematurely, else secondary hemorrhage might occur. Such a major electrosurgical operation should be performed in a well-appointed operating room, using the same preparatory technic as in any surgical operation, though the necessity for sterilization is not as great when the electrosurgical methods are employed as when the cold scalpel is used.


FIG. 87.—Mixed-cell sarcoma of the shoulder. Recurrence after two surgical excisions.
FIG. 88.—Result of combined electrodesiccation and radium treatment. Patient lived 8 years without recurrence.

FIG. 89.—Showing typical recurrence of melanotic sarcoma after surgical excision. The local disease in this case was controlled by employment of the electrodesiccation method when new foci appeared. The patient lived for 5½ years, and finally succumbed to metastasis to the lungs.

Hemorrhoids and Other Rectal Lesions

The electrodesiccation method has proved most satisfactory for the removal of internal hemorrhoids, fissures, fistulas, papillomas, ulcers, and localized malignant lesions of the rectum. The following technic for hemorrhoidectomy is almost identical with that of the clamp and cautery operation, except that electrodesiccation is used as the active agent instead of the cautery.

Technic.—The usual preparation of the patient is carried out. Local infiltration anesthetization by classical technic may be employed,

Fig. 90.—Showing a case of melanotic sarcoma in which a radical coagulation operation was performed. While not successful in absolutely controlling the disease, the operation delayed its progress, prolonged the life of the patient, and decreased the pain.

although in some supersensitive individuals a general anesthetic, preferably ether, is used. Caudal anesthesia is preferred by some operators. After stretching the sphincter muscle sufficiently, each hemorrhoid is pulled down in turn by means of suitable tenacula, and the pile is clamped at its base in the direction of the muscle fibers, which are at right angles with the anus. The pile is then electrodesiccated (by the technic described for other lesions) down to the clamp. The clamp is then removed and the hemorrhoid is permitted to slough away, or it may be excised at once not quite down to the clamp. The latter method is preferred. Postoperative hemorrhage is not greatly to be feared, there is no resulting cicatricial contraction, and as a rule postoperative discomfort is not great. In some cases, however, it is greater than in others. Patients should be hospitalized and remain in bed for a few days as a safe precautionary measure. The electro-

desiccation method for removing hemorrhoids is an advance over the Whitehead, ligature, clamp, and cautery operations and the injection methods, for the radical cure of hemorrhoids.

The electrodesiccation technic described has been found to be more satisfactory for hemorrhoidectomy than the more intense electrocoagulation method. The practice of passing the bipolar, high amperage current (diathermy) through a metal clamp, after the hemorrhoid is engaged in the clamp, is not as satisfactory as the method described, *owing to the possibility of unnecessarily electrocoagulating tissues* adjacent to the hemorrhoids, the greater inflammatory reaction, and possibility of subsequent contracture of the lumen of the rectum.

Breast Amputation by Electrosurgery

In some cases of ulcerated cancer of the breast, when there is not sufficient healthy skin to permit approximation by suturing, the electrocoagulation method may be used. This has the disadvantage of leaving an open wound, which must necessarily heal by granulation. It has the advantage, however, of immediately ridding the patient of a discharging, malodorous, ulcerating growth, with almost immediate relief from pain. It is astonishing how a large healthy ulcer in the mammary gland and other locations, thus produced by electrocoagulation, will heal by granulations without the necessity of skin grafting after removal of the disease down to a healthy base. A note of warning is sounded to use care that the electrocoagulation is not extended through the tissue in the intercostal spaces, lest there be a slough through into the pleura or pericardium.

I am indebted to Dr. Harry E. Mock, of Chicago, Ill., for the following data upon breast amputation by the high-frequency knife, which has a wider field of usefulness in breast work than has electrocoagulation.

Technic.—In breast amputations the skin incision I [Dr. Mock] use is similar to that described many years ago by Halstead. At first I made this skin incision with the high-frequency knife, but in my experience the healing of the skin margins is somewhat slower than when it is made by cold scalpel. Therefore, in more recent years the incision is outlined by the scalpel and barely passes through the skin. The few bleeders encountered are grasped by small hemostats, and are later sealed by barely touching the hemostat with the point of the electrode needle with the current changed to a partly electrocoagulating current. The incision is now carried through the alveolar tissue, fascia, and muscles, down to the ribs, and a clean dissection of the breast, including the pectoralis major and the pectoralis minor muscles, is made upward to the axilla. The smaller vessels are usually electrocoagulated during this cutting procedure, but the larger vessels are grasped by hemostats before the tissues are severed with the cutting current. The cutting current is then turned to an electrocoagulating current, and the hemostats are touched by the electrode until the vessels are thoroughly electrocoagulated. Seldom

are more than two or three ligatures used throughout the entire operation of breast amputation and removal of glands in the axilla. The breast and pectoralis muscles are now turned downward toward the posterior axillary line, after the muscles are severed near their insertion to the humerus; this completely exposes the axilla. A careful blunt dissection of the axillary glands, fat, and connective tissue surrounding the axillary artery and vein, and the lower branches of the brachial plexus, is now carried out in the usual way with the Kocher dissector and tissue forceps. Just as soon as this dissection is sufficiently removed from the axillary artery and vein, the high-frequency electrode is used in carrying out the further dissection of the axilla. Every gland and every bit of fat are removed from above and behind and internally and externally to the vessels, and from behind the margin of the latissimus dorsi and downward to the most dependent angle of the axilla. The breast, the muscles, the glands, and the fatty tissue from the axilla are now completely removed and sent to the laboratory.

A soft rubber drain is inserted through the skin flap into the axilla, its exit being at the most dependent portion of the latter. The skin incision is then closed with silkworm-gut and silk, after making sure that hemostasis is complete.

Advantages.—The above operation can be completed by me in approximately two-thirds of the time consumed in the breast amputation with the scalpel and the ligation of all bleeders.

The majority of these patients have practically no complaint of pain following the operation by this method. Practically every observer has remarked upon the decreased pain when electrosurgery is used.

Histologic studies of the blood vessels and lymphatics show definitely that these are sealed by the cutting current. The fear, therefore, of disseminating cancer cells during the operative procedure is practically eliminated.

Disadvantages.—Hemorrhage following breast amputation has not occurred in any of my cases. However, in one case of removal of a benign tumor from the breast by electrosurgery, a hemorrhage did develop.

In about 50 per cent of the cases, especially if they are fatty subjects, I must admit that there is a great deal more collection of serum in the wound following this method. Great care must be exercised when one passes an electrocoagulating current through a hemostat for the purpose of hemostasis. If the hemostat touches the skin, the latter will be electrocoagulated or burned and will cause considerable delay in the healing of the incision at this point.

In all my breast amputations, whether by the cold scalpel or the high-frequency knife, I have had only one surgical death, that is, death following and traceable to the operation. This case developed a complete pneumothorax followed by a streptococcus infection, with death at the end of one week following the operation. At autopsy there was revealed a small opening in the anterior portion of the axilla between the third and fourth ribs, and extending completely into the pleura. There are two possibilities for this small ulcerated opening: First, it could have been caused by pressure from the end of the drainage tube, as the tube lay exactly in this position; second, it could have been caused by a slough developing at the point of coagulation

of a bleeding vessel. Since this catastrophe, I have guarded against, and have warned others against, the use of too strong an electrocoagulating current over the intercostal spaces.

Results.—I have used electrosurgery in breast amputations for a period of five years. I am positive that more patients are remaining free from metastasis during this five-year period than during any other five-year period of my experience. However, the time is too short to give any statistics or arguments which would be of value in the ultimate end-results. Even if the percentage of recurrences or metastases proves to be equal to the series of cases in which the cold scalpel was used, yet the increased rapidity and ease of this operation by means of electrosurgery, and the reduction in pain and shock by this method definitely warrant its use.

FIG. 91.—One of two similar cases of anthrax infection treated the same day by the electrodesiccation method. These cases were referred from a bacteriologic laboratory, where the patients were accidentally infected. Temperature at the time was 104.2° F. (40° C.). Serum was employed to combat possible blood infection.

FIG. 92.—Rapid recovery in both cases after one electrodesiccation operation. Note good cosmetic result. Photograph taken one year after treatment.

Thyroidectomy with Electrosurgery

Evidence is accumulating that electrosurgery is a valuable adjuvant in thyroidectomy. Its use in this condition was first described by Mock, of Chicago, who gives the following description of this operation. [*J. A. M. A.*, 94: 1365-1368 (May) 1930.]

Technic.—The usual skin incision is made in the neck either with a scalpel, the numerous small vessels, which are always cut, being grasped with small hemostats, or with a purely cutting current, the bleeders likewise being grasped with hemostats. When the incision is made with the active

or cutting electrode, it must be done quickly and accurately in order to obtain a clean-cut incision through the skin.

The next step is to seal the numerous small bleeders exposed by the skin incision. The assistant in charge of the generating machine changes the switch from a cutting to a searing current, and the operator then touches each hemostat in turn with the point of the active electrode (held in the pistol grip). The current passes down the hemostat and seals the end of the vessel, thus eliminating the use of a ligature. Throughout the entire operation practically all vessels are sealed in this manner instead of being ligated. The usual exception is the superior thyroid arteries, which as a further precaution may be both ligated and sealed.

FIG. 93.—Nevus pigmentosus occurring on the abdomen of a young woman. Radium treatment in other hands was unsuccessful, serving only to complicate the case.

FIG. 94.—Result obtained by electrodesiccation after radium failed.

The assistant next turns the switch back to the cutting current, and the operator proceeds to expose the thyroid gland. The incision is now continued with the cutting electrode down through the platysma muscle, and the skin and the platysma flaps are dissected upward and downward the usual distance. These skin flaps are retracted by small nonconducting retractors made of a hard fiber. The cervical fascia is now exposed and is incised down the middle. It is then freed from the capsule of the gland by blunt finger dissection or by a Kocher dissector and is retracted laterally along with the sternohyoid muscles by nonconducting retractors. When in the case of a very large goiter it is necessary to incise this muscle on one or both sides, this incision is likewise done with the cutting current. In many cases in which the muscles have not been overdistended by a large goiter, thus enhancing the ease of their retraction, it is necessary to make a transverse incision as well as the vertical one, and to turn back the four muscular flaps in order to expose the goiter.

The goiter is now mobilized by gently passing the finger around its borders, but no undue traction is used to deliver it into the wound where it can be attached more readily. Clamps are placed on the superior and inferior thyroid arteries, first on the right lobe and later on the left. The gland is now attacked in its superior-lateral aspect, the combined cutting-cooking current being used for dissection instead of the sharp scalpel and hemostats. Occasionally a vessel will bleed and it is necessary to grasp it with a hemostat, but as a rule not more than four or five hemostats are employed on each lobe, and these, with the exception of the superior thyroid arteries, are sealed by passing a cooking current down the hemostat. Such a small amount of this current is necessary, but these vessels are sealed, not electrocoagulated, and there is no area left behind to slough, as is the case when tissue is thoroughly electrocoagulated.

Both the procedure advocated so strongly by Crile, of leaving a small layer of gland behind along the lateral margins and a small film of gland tissue across the trachea, and the method advocated by Reinhoff and others, of opening the internal capsule of the gland and dissecting this off the anterior surface of the goiter and then removing the latter by an intracapsular dissection, have been used. When the latter method is employed, an effort is made to dissect the capsule away from the gland, retracting it laterally, but performing this dissection by means of the electric current rather than by a blunt incision.

The chief purpose of this entire method of attack is to seal not only the blood vessels, but the lymphatics just ahead of the incision, thus preventing the escape of the thyroid toxins into the circulatory (blood and lymphatic) system, with the subsequent severe reactions not infrequently seen following these operations. Therefore, when the goiter proper is reached, every effort is made to avoid the use of scalpel, scissors, or blunt dissector. . . . These are replaced by the cutting-sealing electric current, exactly as is done in the case of a malignant growth in which the desire to seal the blood and lymph channels is even more important.

The bed from which the goiter is removed is now carefully inspected, any bleeding points that appear are sealed with the current, and the remaining edges of the capsule are approximated with plain catgut. A drain of soft small rubber tubing is inserted as a routine. In three cases closure has been effected without drainage, but in one of these there was a considerable collection of serum. In one case a small hemorrhage developed, which was readily controlled by pressure dressing. The skin is closed by fine silk sutures, and the drain is removed in from 24 to 48 hours.

Anesthetic.—The anesthetic of choice in these cases of goiter is 0.5 per cent procaine hydrochloride, used locally. One hour preceding the operation the patient is given morphine sulphate, 1/4 grain (16 mg.), and scopolamine, 1/150 grain (0.4 mg.). With this anesthetic no precautions need be taken on account of the electrical current.

Nitrous oxide gas may be used without undue fear of an explosion, and ether can be used. In the latter two cases a wet flannel roll is placed just below the lower edge of the mask, and further protection against the fumes of the ether reaching the electric spark is provided by a rubber apron placed over the anesthetic frame and held tightly by clips against the skin of the cheeks and chin. In all but one of the cases in this series, local anesthesia was used.

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series that has shown the least evidence of a postoperative thyroid toxicosis. It would seem logical to ascribe this to the same sealing of the blood and lymphatic channels, thus preventing the escape of toxic substances from the cut thyroid gland.

I am not yet ready to say that this will be my method of choice in every case of thyroidectomy. I am, however, convinced that it is by far the most rational procedure in all cases of malignant growths susceptible to being attacked by electrosurgery. For the same reason it would seem an equally rational procedure in malignant conditions of the thyroid, or in severe cases of toxic or exophthalmic goiter.

Disadvantages.—1. The machine for the generating of this electrical surgical current is large and cumbersome, and is transported from one hospital to another with great inconvenience. It is an expensive apparatus, and therefore will usually be purchased only by surgeons or hospitals interested especially in malignant conditions, or by those who may come to recognize its value in thyroidectomy. Its general usefulness is therefore greatly limited.

2. The surgeon must have at hand a carefully trained assistant who understands the mechanism and who can manipulate the various switches that modulate the current from the light cutting stage, through intervening stages, to a heavy electrocoagulating current. Unfortunately, there are only a few persons trained to operate this particular machine.

3. It requires considerable experience to use just sufficient current to make a clean-cut incision in the skin, that will heal as readily and with as little remaining scar as follows a properly executed scalpel incision. With practice, however, this can be accomplished. If too strong an electrocoagulating current is used in sealing the blood vessels, one may have a greater amount of serum drainage than is the rule when hemostats and ligatures are used. Here, again, experience with the current is necessary to overcome this difficulty.

4. Care must be used not to allow the current to come in contact with a hemostat lying across the skin, or a metal retractor; otherwise, cooking of the skin, or of the tissue under the retractor, will follow, to a degree depending upon the strength of the current. This, of course, can be easily avoided.

Conclusions.—1. The value of electrosurgery in the removal of malignant growths of the breasts and other locations where it is possible to attack them by this method has been enthusiastically endorsed by all surgeons familiar with its use. There is no question that this method prevents the escape of carcinomatous cells into the blood and lymphatic streams. It reduces the amount of shock and gives better hemostasis.

2. In thyroidectomies this method prevents the escape of toxic material into the general circulation during the operation, resulting therefore in a convalescence devoid of the severe reaction often seen in these cases. It shortens the operative period by eliminating the ligation of a large number of vessels. It gives a convalescence almost completely free from pain.

3. It has the disadvantage of a cumbersome machine, the need of a trained assistant to manipulate the machine, and the added expense of these two items. But, in spite of these disadvantages, this method should

Number of Cases and Postoperative Course.—Only 15 thyroidectomies have been performed by means of the electrosurgical current. The method is still being studied and compared with the immediate and late results in patients operated on by means of the scalpel with the usual technic. All but 3 of these 15 cases were extremely severe types of hyperthyroidism, with marked loss of weight, rapid irregular pulse rate, and, in four of the cases, marked involvement of the heart. The basal metabolism rates varied from 35 to 89.

During the immediate postoperative convalescence, I have marveled at the almost complete absence of pain in every case; at least 10 of the patients have been completely free from postoperative complaints. In no case has the temperature been elevated above 101.4° F. (38.5° C.), this rise occurring in two cases on the second postoperative day. Six of the other cases showed an elevation in temperature to 100° F. (37.7° C.) on the second and third days, with normal temperature during the remainder of the convalescent period. Five patients showed normal temperature throughout the postoperative period of convalescence.

The basal metabolism rate in all but three of these cases receded to below 10 + by the end of three weeks. Only one patient showed a high rate four months after the operation. He had a preoperative rate of 59 +, and four months later the rate was 35 +, although from a clinical standpoint he could be classed as having recovered. One patient in the series had a rate below — 10, namely, — 12½.

Advantages.—Although this is too small a series of cases to justify positive conclusions, a few definite advantages are apparent:

1. The time of the operation is definitely shortened by this method through the sealing of the bleeding vessels rather than the use of the time-consuming method of applying ligatures.

2. In every case, even in the most serious with marked cardiac involvement, there has been a complete absence of postoperative shock. One patient was in such an extreme condition that the family physician called at the hospital just before the operation and begged both the patient and his wife to forego the operation, stating that he would surely die if submitted to this ordeal; yet the patient made an absolutely normal recovery free from all shock and pain.

3. A convalescence so free from postoperative pain that even the patient remarks about the complete lack of suffering is almost the universal rule. This result occurring in a group of patients who are usually emotional, given to complaints, and often seeking sympathy, is especially noteworthy.

4. When one has used the electrosurgical method in the removal of a large number of malignant growths in breasts, tongues, lips, and parotid glands, one becomes deeply impressed with the bloodless field, the absence of postoperative shock, and the freedom from postoperative pain. The greatest impression, however, and the greatest sense of security lie in the sealing of blood and lymph channels simultaneously with the incision in and around the malignant growth. The old fear of opening up channels for the escape of carcinomatous cells to some other parts of the body is at once eliminated to a great extent.

The same principle holds true in the removal of a very toxic goiter by the electrosurgical method. There has been no case thus far in this small

adds a complication to an already highly complicated procedure. Yet, in making a review of the early histories for purposes of this present communication, I find it expressly stated over and over again that the particular procedure in question, though an extremely prolonged and arduous performance, was one which, without the electrosurgical adjunct, would have been impossible to carry through to a safe conclusion.

During the two years just elapsed since we hesitatingly began to employ the currents in craniocerebral surgery, 547 operations for tumors have been performed. Though for some of these operations the electrical methods were not essential, there were few of them, even when no tumor was found,

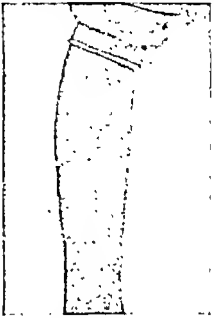

Fig. 97.—Showing a tattoo mark treated by electrodesiccation. The scar noted was hitherto caused by an attempt at excision.

Fig. 98.—The result obtained. Electrodesiccation has been found satisfactory for the removal of tattoo marks.

in which they could not advantageously be employed. The currents are useful even for such trifles as brushing the surface of the dura with the ball electrode in order to seal the torn meningeal veins, from which persistent oozing may sometimes try one's patience, or similarly for checking the persistently oozing points on the under surface of the reflected bone before its replacement, or for electrocoagulating some refractory vessel on the incised dural margin. To be sure, muscle implantation, bone wax, and silver clips have long been used for these several purposes, and they cannot be wholly dispensed with even now, but on the whole, electrical methods usually serve to accomplish the same ends more expeditiously.

Nearly 20 years have passed since Pozzi announced to the Academy of Medicine in Paris a method for the cure of malignancy by the action of sparks from the terminal of an Oudin resonator, a procedure termed "fulguration," as Dr. Bovie mentions in his introductory note. Slowly and grad-

be seriously considered in every case of a malignant disease of the thyroid, and in extreme cases of toxicity with hyperthyroidism.

Dr. Martio B. Tinker, of Ithaca, N. Y., at a recent meeting of the American College of Surgeons, stoted that he found the high-frequency knife to be successful in goiter operations. He stated that "electrosurgical outfits have been used by a nomber of outstanding surgeons in this country for a good many years, especially in the management of malignancy. . . . Their odvantages have become apparent to many members of the profession, and I believe that shortly

FIG. 95.—Nevus pigmentosus treated by the desiccation method.
FIG. 96.—Showing the good cosmetic result obtained.

an electrosurgical unit will be considered a necessary part of every modern operating room, especially where much goiter surgery is done."

Electrosurgery in Brain Lesions

Great advances have been made in the use of the various electrosurgical methods in brain surgery. The following is quoted in abstract form from a paper entitled "Electrosurgery as an Aid in the Removal of Intracranial Tumors," by Dr. Harvey Cushing, which was published in *Surgery, Gynecology and Obstetrics,* December, 1928:

There is no gainsaying that the employment of the Bovie Unit or any other form of current generator as an aid to the removal of brain tumors

taking hemostasis that have largely put a stop to operating by the clock. It has been equally slow to adopt the principles of electrosurgery, which, from a technical standpoint, are likely to be no less revolutionizing.

At a recent meeting of the American College of Surgeons, Dr. Ernest Sachs, of St. Louis, Mo., said that from his experience electro-

FIG. 101.—Angioma of the lower lip; nursing child.

FIG. 102.—Result of radium treatment, which is preferred to electrodesiccation for angiomas of the lip especially in nursing infants.

FIG. 103.—Angioma angle of mouth

FIG. 104.—Result of one office electrodesiccation operation, which treatment is preferred in adults.

surgical methods are indispensable in brain surgery, for the principal reason that he found it possible almost entirely to give up the use of silver clips. His summary is as follows:

1. Electrosurgery is the most important addition to neurosurgical technic that has been devised in many years.

ually this procedure has been modified and extended, until for the treatment chiefly of cutaneous lesions and of orificial malignancy, it has gained enthusiastic advocates.

Surgery is a conservative art. It takes to novel methods reluctantly as an old dog to new tricks. It was slow to adopt the ligature; slow to adopt the principles of antisepsis; slow to adopt the fastidious technic and pains-

FIG. 99.—Extensive keloid following burn.

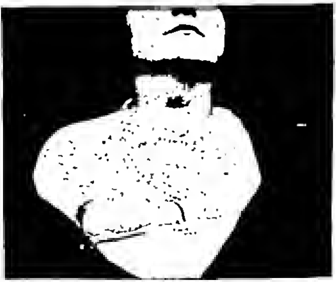

FIG. 100.—Result obtained by well-considered radium treatment, with careful planning of filtration and dosage. This is the treatment par excellence for keloid. Electrosurgical methods should not be employed in keloid, since such treatment will make matters worse.

the same result is a fact that depends entirely upon the individual's surgical technic. It should be emphasized again, therefore, that electrosurgery cannot be said to have superseded the basic principles of osteoplastic cranial operations and tumor removal.

It has been our experience that one is likely to hurry the procedures of electrocoagulating vessels or incising brain tissue. As has been pointed out, the use of a strong current to electrocoagulate a vessel may cause it to explode, and to defeat the object for which it is intended. It is certain that the electrodes are of no service whatever in a bloody field, which does not allow one to see the bleeding or oozing point.

It is of course understood that an electrosurgical apparatus should not be used during the administration of a general anesthetic. The possibility of an explosion is too factual to be dismissed; consequently, the operations in which the electrodes are used are performed under local anesthesia. The dis-

FIG. 107.—Port-wine nevus.

FIG. 108.—Result of ultraviolet ray treatment by the compression method. This treatment is to be preferred to either radium or electrodesiccation in this type of case.

advantage of a general anesthesia, such as ether, in intracranial operations is well known, so that the necessity of a local anesthetic in itself is of value. However, it must be realized that many individuals are not suitable patients for the use of local anesthesia. In such circumstances we have taken the precaution of removing the ether bottle from the room, and have placed a wet cloth between the patient's face and the operative field while the unit is in use.

We have satisfied ourselves that there are no untoward or disturbing complications due to the use of this apparatus in intracranial surgery. As a matter of fact, the immediate postoperative convalescence in all the cases in which it has been used has been smooth and uneventful. We have never had to reëlevate a flap in this group of cases because of secondary hemorrhage; neither do we believe that any greater amount of postoperative edema follows its use. In conclusion, we believe that:

2. By means of this method brain tumors can be dealt with that have been inoperable heretofore, and tumors that were operable can now be removed with greater safety.

3. The technic of this procedure takes time to learn, and as our experience increases and its possibilities are realized, more and more can be accomplished with it in the future. [*Surg. Gynec. Obst.*, p. 505 (Feb.) 1931.]

FIG. 105.—Extensive cavernous angioma of cheek extending almost through into the mouth. The major portion of the lesion was covered by healthy skin, but an elevated strawberry-colored surface angioma may be observed in the photograph.

FIG. 106.—Showing result of an electrocoagulation operation; the blood lake was coagulated and later removed through the external angioma. Note retrogression to normal with small uncontracted scar. Four similar operations were successfully performed before radium was employed for such cases. Radium is now preferred because of less hazard.

The following, relative to brain surgery, is kindly contributed by Dr. Loyal Davis, Professor of Surgery of the Northwestern University Medical School:

There can be no doubt that the use of electrosurgery adds a complex piece of surgical equipment to a technic already dependent upon meticulous attention to detail for its success. The surgeon of course does not have to be acquainted with all the laws of electrical physics to employ such an apparatus successfully. However, a thorough acquaintance with its performance obtained upon experimental structures is necessary before one should attempt its use during a complicated surgical procedure. Even with such a preparation, the advantages and limitations of its use are indicated more clearly by practice. That some surgeons may find it of more value than others to gain

not as greatly to be feared when the high-frequency knife is employed as after the cold scalpel. He further states that he has performed five laparotomies for the purpose of dividing extensive intra-abdominal adhesions by the electrosurgical knife, with no recurrence of the adhesions, as evidenced by the permanent disappearance of the characteristic discomfort caused by them. In a recent communication, Trowbridge stated that he had successfully performed nephrectomy and hysterectomy and had removed a renal calculus by means of the high-frequency knife.

FIG. 112.—Cavernous angioma and necrosis of bone from excessive radium treatment hitherto given by another physician. Patient almost lost life from hemorrhage.

FIG. 113.—Result of one electrocoagulation operation.

Electrosurgery in the Genito-Urinary Field

The same indications for electrosurgery exist in the genito-urinary as in the gynecologic field. This can be extended in the male to prostatectomy through a suprapubic opening by means of the high-frequency knife. Some surgeons have advocated employing a wire loop as the knife in the use of the high-frequency cutting current for severing and removing the median bar of the prostate by way of the urethral route through an operating cystoscope, as an improvement over the Bottini operation.

Excellent results have been reported by surgeons who are in a position to judge of the merits of electrosurgery in this field. The successful removal of papillomas from the bladder by means of the high-frequency current through an operating cystoscope, which was first described by Beers, and verified by many others, is impressive to those who have seen the operation performed. The treatment of such lesions has been revolutionized by the advent of electrosurgical methods. I have successfully stopped hemorrhage and removed numerous papillomas of the bladder by the high-frequency method. The first one in

1. Electrosurgery is a distinct addition to the neurologic surgeon's armamentarium. It does not, however, completely supersede the well-established principles of osteoplastic cranial cerebral surgery.

2. At present it may be employed to its greatest extent in the removal of meningiomas, in particular to the relatively inaccessible meningiomas.

3. The improvement of the use of electrosurgery in the treatment of gliomas offers the possibility for its greatest contribution to the surgery of the nervous system.

FIG. 109.—Extensive cavernous angioma.

FIG. 110.—Showing improvement during radium treatment.

FIG. 111.—End-result of radium treatment, a method which is preferred to electrosurgical methods in this type of case.

Electrosurgery in Gynecology

Electrosurgical methods have a very definite value in a wide range of conditions of interest to the gynecologist. Among the minor lesions in this field which can be successfully treated by the electrodesiccation method are venereal warts, leukokeratoses, leukoplakia, condylomas, moles (simple and pigmented), chancroids, angiomas, some localized cases of pruritus (of nerve or eczematous origin), urethral caruncle, urethral prolapse, erosions and infected Bartholin's and Skene's glands, lupus, fissures, fistulas of vagina and rectum, polypi, papillomas of the bladder (operating through a cystoscope or a suprapubic opening), papillomas of the vagina, cervix, and rectum, erosions of the uterine cervix, endocervicitis, hemorrhoids, epitheliomas, chancre (influencing the treatment and progress of syphilis), and carcinoma of the cervix in combination with radium.

The larger growths may be treated by the more powerful coagulation method. The high-frequency knife has a wide field of usefulness in pelvic surgery, such as hysterectomy, through an abdominal incision, and evidence is accumulating that the future for this method is promising throughout the whole range of gynecologic surgery. This is also true of surgery of the upper abdomen and thorax. An interesting observation has been made by Trowbridge, that adhesions are

the lesion can be removed with the same ease and simplicity as though it were on the skin surface. The wound will heal readily if the patient is normal, and some notable results have been obtained.

I have had under my observation a case of squamous-cell carcinoma which was treated by this method, and the patient has been free from recurrence for 10 years. In extensive carcinoma of the larynx, com-

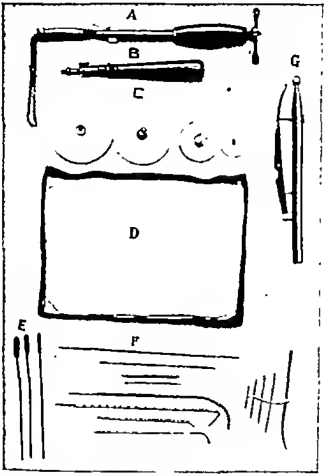

FIG. 114.—Showing some instruments employed in electrodesiccation and electrocoagulation.

A. Metallic snare which can be used as the active electrode for electrocoagulation and removal of certain large pedunculated growths. Fig. 70 is an example.

B and C. Handle and metallic discs utilized as passive electrodes when localized destructive effects are desired. Fig. 70 is also an example. The active snare was employed around the pedicle and the passive disc on top of the glioma.

D. Asbestos electrode covered with rubber on one side and duck on the other. When moistened and placed on the back of the patient it serves as a satisfactory passive conductor in electrocoagulation work.

E. Electrodes of copper, suitable for electrocoagulation treatment of such conditions as endocervicitis or endometritis.

F. A variety of needles employed as active electrodes for electrodesiccation and electrocoagulation work.

G. Handle designed by Cooke, to hold needles for electrodesiccation and electrocoagulation operations.

1910 was a bleeding papilloma almost the size of a hen's egg. The patient, an aged man, lived for seven years free from recurrence. I have found from experience, however, that unless the lesion is benign, it should be treated through a suprapubic incision and an opening into the bladder. In this case other methods may be employed in conjunction with the electrosurgical method.

Electrosurgery in Eye, Sinuses, Ear, Nose, Throat, and Larynx

Electrodesiccation may be employed in the following eye lesions without causing a contracted scar: neoplasms of the eyelids, canthi, bulbar and palpebral conjunctiva, such as epitheliomas, sarcomas, warts, moles, nevi, dry granular conjunctivitis, trachoma, leukoma, refractory corneal ulcers, lupus, permanent removal of cilia from eyelids when indicated, xanthoma, chronic local infections, etc. When complete exenteration of the orbit and adjacent sinuses is indicated, or when adjacent bony structures are involved with disease, electrocoagulation, in many instances, may be relied upon to accomplish superior results, provided the technic is thoroughly understood. Great care must, however, be taken to avoid injury to orbital bones, else the dura will be exposed and meningitis will result.

The same types of lesions noted in the preceding paragraph, occurring on or in the ear canal, may be successfully treated by electrodesiccation or electrocoagulation, the choice of method depending upon the extent of the disease. It might be noted as a matter of interest, and to illustrate the delicate action of the current, that small granulations of the tympanum may be removed by electrodesiccation without injuring that delicate structure, so great is the refinement of its control.

Lesions on the nose of the same type mentioned above may also be successfully treated by electrosurgical methods.

Electrodesiccation has been found useful in the removal of hypertrophied turbinates, polypi, papillomas, epitheliomas, etc., of the nasal mucous membranes, without causing the hemorrhage incident to the use of the cold scalpel.

There are numerous indications for electrosurgery in its different forms in the throat, such as tonsillectomy, removal of papillomas, lupus, leukoplakia, and certain malignant lesions. The electrodesiccation method is satisfactory for the removal of accessible papillomas of the vocal cords. This operation can be performed by either indirect or direct vision, through a laryngoscope.

Cancer of the larynx, however, should not be treated through the mouth, owing to impossibility of doing complete work, and also owing to the hazard of injuring normal structures. It is preferred that a preliminary tracheotomy be performed, and after that a laryngotomy, by a longitudinal incision. In this manner the lesion can be properly exposed and palpated to determine its location and character. Then

however, regarding the value of this method, some commending and others condemning it. This has caused confusion in the minds of those who are sincerely seeking authentic information.

FIG. 115.—Section of basal-cell epithelioma removed before the application of electro-desiccation, showing bulky masses of infiltrating basal cells.

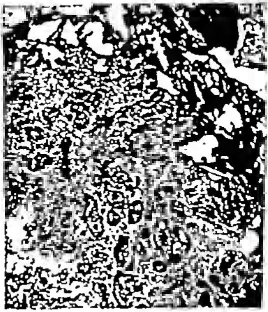

FIG. 116.—Section from the same growth as Fig. 115, showing the result of electro-desiccation treatment. The cellular masses are definitely shrunken and the nuclei condensed and elongated.

plete laryngectomy is sometimes indicated, and in this work the electrosurgical knife may be found to have a field of usefulness.

Tonsillectomy by Electrosurgical Methods

May I state at the outset, that it is the opinion of conservative laryngologists that electrosurgical methods will not entirely replace the operation in use for many years, owing to satisfactory results obtained with the latter in the average case. This is probably true, but it is also quite well known that in certain instances there is a distinct contraindication to the open operation. If, therefore, electrosurgical methods can be used in such cases with the hazard minimized, then there is a valid reason for including them among the methods to be considered by laryngologists when unusual conditions exist.

Experience with electrosurgical methods in tonsil work has been multiplying, and while discounting the ultra-laudatory opinions of the overenthusiasts, it now appears safe to say that some electrosurgical methods may be relied upon as worthy substitutes for the open operation, in cases where there is a distinct contraindication to its use, especially in the case of adults. This is true, provided a proper and standardized technic is employed. Three electrosurgical methods have been advocated for tonsillectomy, namely: the high-frequency snare, electrocoagulation (diathermy), and electrodesiccation, which in turn will be briefly discussed.

High-Frequency Snare.—A few laryngologists have suggested the use of the high-frequency snare for tonsillectomy. The same current used for cutting (bipolar) is passed through a metallic snare, and the tonsil is removed by the same technic as in the cold snare operation, except that the current is used while the snare separates the tonsil from its bed. Its advocates claim that the possibility of hemorrhage is less, and that it has the further advantage of sterilizing the operative field. While it undoubtedly has these advantages, it has not been adopted for general use because of the greater care necessary for the proper control of the current, lest other structures in the throat be damaged. In common with any known method, the danger of hemorrhage is, however, not entirely avoided, regardless of primary capillary sealing. It would not be entirely safe to depend upon it permanently to seal the normal or anomalous larger vessels that may be encountered. It is doubtful what the future appraisement of this method will be, but at the present time, at least, it is not as popular as the electrocoagulation (diathermy) or the electrodesiccation methods (unipolar) for tonsillectomy.

Electrocoagulation (Diathermy).—The electrocoagulation effect produced by the bipolar d'Arsonval current of high amperage and low voltage has been widely employed during recent years for the removal of tonsils, with a fair measure of success. Published opinions differ,

Method No. 2 is perhaps more generally in use than the others and is quite satisfactory if correct technical rules are observed.

Method No. 3 bids fair to be popular also, and those who employ it believe it satisfactory.

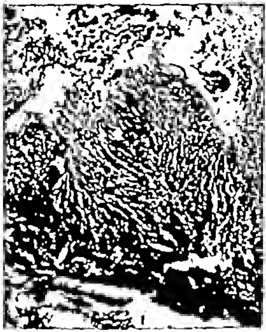

FIG. 117.—Section of basal-cell epithelioma of the cheek treated by electrodesiccation. The devitalized cells appear as long slender threads—"mummification necrosis."

FIG. 118.—Squamous-cell epithelioma treated by electrocoagulation, showing an extensive area resembling hyalinization and several thrombosed blood vessels. The tumor cells seem to have fused into a structureless mass.

Paradoxical as it may seem, the different estimates of its value may all be correct, each depending upon the point of view. This is explained by the fact that high-frequency currents are characterized by, and subject to, great flexibility, both as regards the mode of production and also in the effect produced by them in the tissues. A wide range of effects can therefore be obtained from their use, depending to a great extent upon the construction of the apparatus which generates the current in such details as the capacity of the condensers; the number of windings and the thickness of the wire in the primary and secondary coils and in the solenoid to produce the proper inductance; the character of the spark gap to insure the correct resistance; and lastly, the technic of application.

For example, ten operators, conceivably of equal ability and experience, might in all sincerity and accuracy report their findings, but with no two of them exactly agreeing. This is explained by the fact that none of them employed the same electrical factors nor the same technic in their work. Thus the views of diverse nature are explained.

In the course of development of any important invention, a condition of uncertainty is to be expected for a time, until all factors are standardized toward the end that maximum efficiency will be attained by all employing them.

There are four methods in use for employing electrocoagulation (diathermy) in tonsillectomy:

1. Destroying the tonsil as completely as possible at one operation, employing an active needle electrode, and a passive metallic electrode on the back of the patient.

2. The removal of the tonsil in small portions in a series of treatments, employing an electrically activated straight or hooked needle as the active electrode. Multiple punctures in the tonsils are thus made and the indifferent electrode is placed upon the back of the patient.

3. The use of a metallic ring electrode which encircles the tonsil, and when pressed inward exposes the tonsil to view, and also acts as the indifferent electrode. The active electrodes are straight or hooked needles, insulated except at the point, and the tonsils are removed little by little in a series of treatments, also by means of multiple punctures.

4. The removal by means of two insulated hooked electrodes clamped together like a tonsil forceps, and used at the same time, each carrying the current from opposite sides of the high-frequency machine. By this method the tonsils may possibly be removed by one operation, or better, by a series of operations.

Method No. 1 has been discarded by most operators because the inflammatory reaction is too great, and the danger of destroying adjacent structures in the throat and of secondary hemorrhage is to be seriously considered as a possible hazard. It is therefore not recommended for general use.

A whole gamut of effects may be produced in tissues by the various manifestations of electrical currents, some of which are desirable for the treatment of certain lesions, though contraindicated for others.

I prefer to speak in definite terms of effects when possible, rather than of general methods. For example, the term "drugs" will help little in prescribing for a definite ailment, whereas, "digitalis" can instantly be recognized as the particular "drug" to be administered in certain heart lesions. The use of such terms as electrosurgery, diathermy, endothermy, etc., though proper in their place as general terms, is therefore analogous to the use of the term "drugs," which is indefinite in description of the particular drug actually employed, whereas electrodesiccation, selected from a wide range of thermic electrical effects, is a known entity like "digitalis," and can be standardized for definite uses, one of which is for the successful removal of tonsils, as well as certain other lesions before mentioned. Electrocoagulation can likewise be distinguished from electrodesiccation, with its definite indications; and again the effect of the high-frequency knife upon tissue is dissimilar to either, though in turn of value, when it would be improper to use the other electrosurgical methods.

It can therefore be seen that general terms are not conducive to a close understanding among scientific observers, while standardization of methods in terms of effects and special technic will permit of duplication of results by different surgeons. Out of the range of effects of applied electricity for surgical uses, electrodesiccation, electrocoagulation, and the high-frequency knife have up to this time been found by experimental studies and clinical use to be more practical and useful than others thus far recognized.

The harnessing of Nature's mysterious force by patient workers in the surgical field for the alleviation of human suffering is an achievement comparable with the greatest in surgical annals. This sentiment has been voiced by some of the most critical minded of our profession.

Method No. 4 seems a rational procedure, but its real value has yet to be demonstrated since so few laryngologists have thus far employed it.

Inquiry regarding removal of tonsils by the series treatment method among experienced laryngologists reveals that complete work is seldom accomplished in less than six treatments to each tonsil, in periods varying from seven days to two weeks between treatments. Some operators employ as many as 20 to 25 treatments. Seldom is complete removal accomplished in any case in less than three months, and it sometimes requires six months or more. It would seem that such prolongation of inflammation would be objectionable, but I am told by those who employ it that patients do not object to it.

All four methods have been fully described in current medical literature which is readily available, hence no attempt will be made to enter further into discussion of them in this chapter.

In fairness to all may I state that these methods no doubt are successfully employed by capable men who have studied and applied them, but, in common with any method designed for a definite purpose, some disadvantages are almost sure to exist.

Electrodesiccation.—From my experience with the use of all types of high-frequency currents for general surgical purposes for nearly 25 years, I prefer the unipolar current of low amperage and high voltage for the removal of tonsils. May I therefore not be accused of bias if I differ somewhat from those who prefer any form of the bipolar, high amperage, and low voltage current (diathermy).

My growing impression is that electrodesiccation possesses fewer disadvantages, and that it is more suitable for delicate throat work, than electrocoagulation (diathermy), inasmuch as there is better control with electrodesiccation; the inflammatory reaction is slighter; there is, I think, less resulting fibrotic change; the hazard of secondary hemorrhage is less to be feared; the natural contour of the tonsillar fossa is better maintained; the work is completed in fewer treatments; and the results are all that can be expected of any method.

Analysis of adverse reports concerning electrodesiccation in tonsillectomy reveals misunderstanding of the method and the employment of an improper technic.

Electrosurgical methods for tonsillectomy should be practiced by laryngologists when indicated in complicated cases, but to insure the best results, careful study and mastery of technic are necessary, else they will be disappointed with results.

Conclusion

The term *electrosurgery* is a broad one, expressing so many ways and means of applying various forms of electrical energy for the removal of abnormal tissue as often to cause confusion in the minds of those seeking reliable information.

A whole gamut of effects may be produced in tissues by the various manifestations of electrical currents, some of which are desirable for the treatment of certain lesions, though contraindicated for others.

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CHAPTER TWENTY-ONE

ELECTROSURGERY AND OTHER PHYSICAL THERAPY MEASURES IN UROLOGY

F. G. Harrison, M.D.

Papilloma of the Penis

Verrucae acuminatae, known commonly as venereal warts, although by no means always associated with any venereal disease, are caused by irritation from some source, usually from the prepuce. They are an overgrowth of the papillary layer of the skin or mucous membrane.

They are mostly papillary in type and composed of epithelium which is readily transplantable to produce neighboring buds. They may resemble epitheliomas or condylomas, from which they must be differentiated.

Correction of the irritation, whether from uncleanliness or discharges, often causes disappearance. Balanitis and phimosis must be corrected to prevent recurrence, and this may necessitate circumcision.

While the ordinary treatment is the application of nitric or trichloracetic acid, if not applied carefully and the excess mopped, the surrounding mucous membrane is likely to be destroyed.

The most satisfactory results are obtained by applying 10 to 20 per cent cocaine solution directly to the growth. After allowing a few minutes to elapse for the anesthetic to take effect, a fine needle electrode is introduced at the base of the growth and it is destroyed, using the monopolar high frequency and a low current.

A dusting powder and a dry dressing may be applied, the warts either dropping off with treatment or in a few days.

Chancroid

Any genital ulcer is regarded as a chancre until proved otherwise. While the incubation period and the clinical characteristics may be such as point to a chancroid, it is the golden rule that no treatment should be started until an absolute diagnosis is made. The dark field examination for *Treponema pallidum* is positive in well over 90 per cent of untreated cases on the first examination. For those sores which have received local treatment, especially preparations of mercury, it is essential that all this be removed and the suspected ulcer cleansed and bathed in normal salt solution by repeated applications. The

and with progression may break down and discharge pus from secondary infection or become a lesion like the initial focus.

As epithelioma is uncommon before the fortieth year, the diagnosis is made by exclusion. Biopsy is not recommended, unless just prior to operative procedure, as it has a tendency to promote metastasis.

Similar to cancer elsewhere in the body, the prognosis depends largely upon an early diagnosis with prompt and efficient treatment. The later in life the condition develops, the slower it seems to grow. Prognosis is good if seen early, and while it has been stated that should inguinal lymph node involvement occur, cure is doubtful, yet many are reported.

Roentgen rays, surgery, diathermy and radium are the agents employed in the attack, either alone or combined; but it depends upon the site and duration to some extent. Surgeons have stated that the epithelioma involving the glans or distal third of the penis may be treated by partial amputation, but that which extends to the middle or proximal third demands extirpation.

Preoperative roentgen-ray therapy of not more than one treatment is always advised. A preliminary block dissection of the inguinal glands is carried ont prior to the radical surgery on the penis. These glands may be destroyed by diathermy, by placing the flat disk active electrode over the glands after exposure by the skin incision and slowly heating until the gloved finger cannot be borne on the tissues and with repetition. Due care must be given to the femoral vessels which lie beneath.

The partial amputation is carried out with due respect for the skin flaps, and placing and suturing of the cut urethra to prevent contracture and stricture formation of the new meatus.

Complete extirpation is performed in the same manner, with the new urinary meatus brought out to prevent stricture formation.

Intensive postoperative roentgen-ray therapy is routinely advised. Complete emasculation is rarely employed, and in recent years there seems to be a tendency, whether warranted or not, to avoid the knife because of discouraging resultant metastasis, and to employ measures that produce no mutilation with tendency to regional metastasis.

Diathermy has been used in the treatment of epithelioma, employing the bipolar current with the inactive electrode beneath the sacrum and a flat disk active electrode. General anesthesia is not necessary. The cancerous tissue is destroyed by the slow process of thermo-electrocoagulation, avoiding all sparking, and the coagulatiou is carried out well beyond the diseased area to the normal healthy tissue to insure complete destruction of the growth.

The same procedure as detailed above is carried out with regard to the inguinal glands. Preoperative and postoperative roentgen-ray therapy is advised.

Pfahler and Widman report a series of cases which were treated by radiotherapy and electrocoagulation. Certain cases respond better when

physician who neglects this dark field examination or, if not possessing the facilities to carry out this procedure, fails to direct the patient to where it can be done is guilty of moral malpractice, at least.

If dark field examinations be negative for three or four successive days, and if the Wassermann reaction be negative, local treatment may be applied. It is wise to continue weekly serologic examinations until the sixth week or the secondary period has been passed.

Many chancroids can be cured by correcting the hygienic habits of the patient, as uncleanliness is usually the forerunner. There are many remedies offered for cure, such as application of caustics and acids, but the writer has found that crystals of argyrol are very efficient and where this is unsuccessful or by reason of the phagedenic spread, the method recommended by Robbins and Seabury is applied.

The chancroid is cleansed and a 10 to 20 per cent solution of cocaine is applied directly with a swab, which is held in place several minutes. A liberal application of 25 per cent cupric sulphate is made to the excavated area, and with the monopolar current of the diathermy apparatus and the vacuum electrode, the ulcer is completely fulgurated, care being given to carry the destruction well under the undermined edges and beyond.

Corbus has pointed out that using a fine needle as an electrode and desiccating the sore, rather than sparking it, is superior, as it does not carbonize the tissues and at the same time permits greater heat penetration. The grayish-green area is now covered with a dusting powder, and, if there should be any spread, the procedure may be repeated. Usually in a few days the phagedenic ulcer has been changed to normal, healthy granulation tissue.

The accompanying unilateral inguinal adenitis may be treated with diathermy if seen before suppuration occurs. The smaller electrode is placed over the inflamed gland and the larger one beneath the buttocks and treatment given for 40 minutes, repeated daily. Should suppuration occur, incision and enucleation of the gland are indicated.

Epithelioma

The etiology of cancer of the penis is unknown, but it has been recognized that a long and adherent foreskin, with resultant irritation from smegma and a chronic balanoposthitis, predisposes. Epithelioma among the circumcised is rare.

This condition arises on the glans or prepuce, frequently on the site of an old scar formation. Keyes reports it may start as an indurated nodule under the skin or as a patch of leukoplakia. Beginning as a wart on the skin, or an ulcer, it becomes deeply ulcerated with granulating or cauliflower-like growths with a foul seropurulent discharge. It may spread and involve the entire penis and adjacent structures. It is slow growing and pain is usually not an early symptom. The regional lymph nodes are reported as becoming involved rather late,

ducing fever or who develop influenza or acute febrile conditions. Santos in his experiments reported that 43° C. (109.4° F.) for 76 *minutes, 44° C. (111.2° F.) for 54 minutes and 45° C. (113° F.)* for 37 minutes were necessary to kill gonococci. It has been shown by others recently that *in vitro* the gonococcus will survive 30 minutes at 45° C. (113° F.). The point is whether experimental studies of the gonococcus grown *in vitro* help us determine their relative resistance in the tissues. It may be analogous that, despite recent research to discover a chemical gonococcicide, the urologist frequently returns to the old established irrigant—potassium permanganate—notwithstanding the fact that its germicidal properties are much less than many others. It would seem, therefore, that if by applying diathermy we create an unfavorable condition for the viability of the gonococcus, without disturbing the mucosa, we are accomplishing enough to warrant its trial.

Nagelschmidt, with reference to the male urethra, states, "Theoretically, it would be easy to apply heat deeply with diathermy, but practically it is quite different. In order to obtain an even, deep heat, one must apply diathermy with low amperage during a long time. It is technically very difficult to diathermatize the whole urethra far into the bladder without heating up some places too high. In the pars pendula no difficulties appear. As soon as we reach the root of the penis, it is impossible without special technic to heat through the urethra in all directions with an even temperature." Corbus and O'Conor in their book state, "It is a firm belief that ultimately the technical difficulties which so far have prevented the absolute perfection of this method will be solved."

The use of medical diathermy in the treatment of acute gonorrhea has been upheld by many authors—Roucayrol, Seres, Walker, Watson, Canovas, Cumberbatch and Robinson, Corbus and O'Conor, Gomez and Gastano, H. Schmidt, Nagelschmidt, Shohan, MacArthur, Redewill and others—but has been discounted by recent textbooks of urology, notably those of Keyes, Pelouze and Eberhart in this country and MacDonagh of England.

It is not within the scope of this chapter to discuss the physical principles which govern the development and application of the type of current suitable for diathermy. It is sufficient to state that should this method be employed, it is essential to get a good machine which will deliver all that is expected of it with a margin to spare. It should be capable of delivering *2000 to 3000 ma. in a steady volume* without appreciable variation over a period of one hour. Small machines incapable of doing this do not produce results. Whether a portable machine is desirable is a personal decision. We like a portable machine because it can be moved from one room to another or even to the patient's home. MacArthur in a personal communication informs me that he has a large machine with connections such that two patients can be treated at the same time. Of the greatest importance are the

radium is applied together with roentgen-ray therapy. Amputation was carried out by electrocoagulation at approximately the junction of proximal and middle third, without regard for the urethra. There is no record of stricture formation and in a personal communication I am told there was none. While the method of amputation with electrocautery produces a bloodless field, most surgeons would regard the abandoning of the new urinary meatus to its fate as hazardous.

Gonorrheal Urethritis

Electrotherapy with the production of heat in the tissues in the treatment of gonorrhea is by no means new, yet the evaluation of this method has not been firmly established. This may be due to the misleading and colorful statements of enthusiasts or to the doleful negative confirmation of the doubters. There is no specific cure for gonorrhea, and, as diathermy is the production of electrical heat, it is useless to expect results other than those derived from heat actively generated in the tissues. It is a biologic finding that under all conditions heat up to the optimum point increases the activity of tissue cells, and down to a minimum point decreases the activity of the tissue cells, which leads to the conclusion that the production of heat in the body tissues increases cell activity, and thus the inflammatory reactions to an irritant are greatly accelerated.

Medical diathermy has been regarded as having marked analgesic properties. It increases cell activity and hyperemia, with its resulting slowing of the blood stream due to the dilatation of the blood-vessel walls. It increases diapedesis both in rate and amount, and accelerates phagocytosis. It produces a deleterious effect directly upon the invading irritant and decreases the amount of scar-tissue formation, as the first changes in inflammation are accelerated and also reabsorption takes place faster.

The contraindications to diathermy are few but must be understood. It cannot be substituted for surgical drainage in a collection of pus—as diathermy may aggravate the condition, and septicemia results. It should never be used where there has been any hemorrhage or where there is possibility of any.

The gonococcus has long presented cultural difficulties making it next to impossible to obtain growths except under the most favorable conditions, as the pus obtained at epididymotomy. Recently with the introduction of the calf-brain media and attention to hydrogen-ion concentration, it is reported the organisms may be cultured from the urethral pus. It would seem that conditions have to be most favorable for its growth, and, as the gonococcus is not very hardy, the least unfavorable circumstances will have a tendency to destroy it. It has been a well-established fact that excess heat has a deleterious effect upon the gonococcus. The clinical course of acute gonorrhea has been markedly lessened in those individuals who have complications pro-

and thus surgical diathermy or fulguration is apt to occur with a resulting traumatic fistula.

Following the suggestion of MacArthur, the writer applies diathermy to the anterior urethra, using two strips of block tin ½ inch wide, cut to a length which will run the entire urethra, anointed with K-Y lubricating jelly and strapped with adhesive. Attention is given to directing that the electrode on the floor of the penis be slightly smaller, as the urethra is closer to the floor. Intimate contact of all electrodes is most essential, and it is best to have all cords completely insulated to the very point of attachment. A small rubber cuff can be slipped over this point after the connection has been made. It is

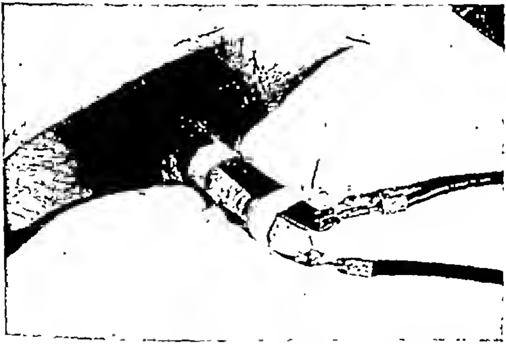

FIG. 1.—Strip tin electrodes cut to length along the anterior urethra, held in place by adhesive. Rubber cuffs may be pulled over connection points to prevent shock. (After MacArthur.)

desirable to increase the current slowly, taking at least five minutes before maximum intensity is produced, and reverse the procedure for cutting off the current. As there is no thermometer to act as an indicator, the milliamperemeter must be watched, with the current varying between 300 and 800 ma. The length of the treatment should be at least 1 hour and should be repeated daily or, better, twice daily until the gonococci are eradicated. The temperature of the urethra can be raised to 109 to 112° F. (42.78 to 44.44° C.) for the duration of the treatment, a temperature at which it is alleged the gonococcus is destroyed. This treatment can be continued for some time (Fig. 1).

electrodes, which will be discussed under each condition because it is here the personal element enters.

Provision has to be made so that the patient can lie for an hour or more without being disturbed and, if not under personal supervision the entire time, at least watched by someone competent to judge if the patient is getting what is desired. Better results are obtained by arousing the interest and coöperation of the patient, by explaining carefully to him exactly what you wish to accomplish and assuring him that there will be no shocks or painful effects. After the first application with no untoward effects, the patient's morale is raised, particularly with clinical improvement, and afterward the cord connecting with the switch is given him so he can break the circuit if the heat becomes too intense.

It would seem that diathermy will never become popular, at best, mainly from economic reasons. The physician needs special, expensive apparatus, a separate room for an hour or more, and the procedure must have skilful supervision. Of necessity a larger fee must be charged to the patient, who in these times of economic stress is more than likely unable to pay it. Thus it will be shelved except for the wealthy, or in those distinct cases where diathermy is so superior to other forms of treatment that self-preservation of professional rank will impel its use.

To the patient presenting himself with acute gonorrheal urethritis in the early stage, i.e., the first or second day, with the infection limited to the anterior urethra, anterior to penoscrotal juncture, diathermy may aid in effecting a speedy cure. By the two-glass test, the first may be cloudy and contain a few shreds, but the second should be clear. Theoretically this is the time, if diathermy is able to sterilize the urethra by killing the gonococci, the best results should be obtained, comparable to a successful so-called abortive treatment, which is seldom employed. The great difficulty has been to get a suitable set of electrodes which will give even heat to the urethra. Various types of intra-urethral electrodes have been devised, notably the one by Corbus, which is unsuccessful because:

1. A basic urologic maxim states that no instrument should be passed in the inflamed urethra in the presence of gonococci.

2. Patient is usually not able to tolerate instrument in the inflamed urethra for sufficient period of time to get desired result. Corbus states however, "Contrary to the general impression of this form of treatment, it is painless during the period of application. After the withdrawal of the thermophore there is a copious discharge of serum and mucus which lasts until the next urination." The writer does not favor this treatment.

3. As the urethra is not of uniform caliber, an electrode does not fit snugly against the mucosa, so that sparking will occur.

4. Heat is liable to be concentrated on the tip of the instrument,

has not been so favorable, whether because of faulty technic or because we failed to get proper coöperation from our patients. In most cases the discharge appeared a little more profuse after the first treatment and then gradually cleared. The acute symptoms were alleviated. Gonococci did not seem to disappear any more quickly than with other methods. Clinic patients are difficult to hold to treatment, particularly when the symptoms with which they present themselves have abated. It has been observed that, as our technic improved, better results were obtained, and we are inclined to blame ourselves rather than the method for our earlier failures. We do not advocate this as a routine treatment for acute urethritis.

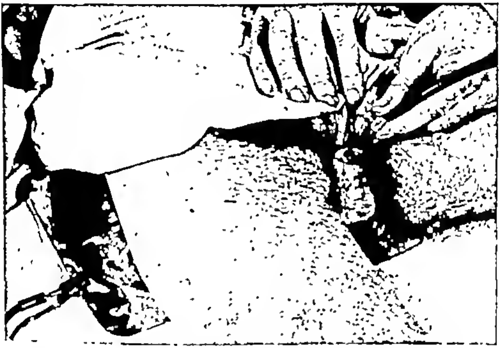

FIG. 3.—Localized inflammation in perineum—Cowper's gland. Small block tin electrode over affected area and held in place by adhesive after shaving. Large electrode (6 by 8 in.) beneath buttocks.

With posterior involvement of the urethra, which occurs in the majority of cases treated by any means, complications may occur, and it is here that diathermy occupies first rank in the treatment. Prophylactic treatments to the posterior urethra and prostate have been advised at this time, where there has been a period of inactivity with older methods.

Periurethritis may occur anywhere along the urethra, but the commonest sites are immediately posterior to the glans penis and in the perineum. The latter may be due to extension from the glands of Littré or from inflammation in Cowper's glands.

This treatment does allay all the acute symptoms and checks the discharge considerably, even if the infection has invaded the bulbous portion of the urethra, and can be used in conjunction with the various accepted modes of treatment, as internal medication, hand injections or irrigations, copious draughts of water, free catharsis, restriction of exercise and diet, and a taboo to sexual excitement and alcohol.

In the acute fulminating types where the penis is edematous, the tips of the meatus and the prepuce are swollen and the patient complains of intense dysuria, palliative treatment alone can be instituted, as injections or irrigations are not indicated or tolerated, and dia-

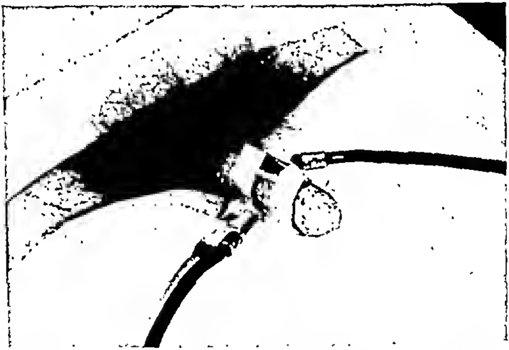

FIG. 1.—Molded block tin electrodes held in place by adhesive straps in periurethritis. Larger electrode on top—smaller on bottom. Rubber cuffs may be pulled over connection to avoid shock.

thermy occupies a stellar rôle and acts as an excellent palliative measure, as often one treatment will entirely relieve the acute symptoms, and injections can be resumed shortly.

Redewill *et al.* in a recent article maintain that with properly applied electrodes external to the penis, the urethra having been previously filled with 0.5 to 1 per cent mercurochrome, uniformly excellent results can be obtained with the use of diathermy.

MacArthur reports a series of 15 cases of acute gonorrheal urethritis in which, after the fifth diathermy treatment, the gonococcus could not be found in 14. In two cases a recurrence was noted.

Our experience with diathermy in the treatment of acute gonorrhea

A patient with acute prostatitis is a hospital case, because the effectiveness of the treatment directed to the prostate in the first few hours will determine the future management. It is here that a portable diathermy machine is indicated, for it can be brought to the patient's bed. The patient is placed on his belly, with the larger so-called inactive electrode of block tin, approximately 6 by 8 inches, anointed with soap lather or K-Y lubricating jelly, beneath the lower abdomen. The buttocks are spread, with one hand, and the prostatic electrode, copiously anointed with lubricant, is introduced easily and carefully into the rectum, directing the concave metal portion to come in actual contact with the diseased portion of the prostate, as having been previously determined by rectal palpation. This may be turned to various areas during the treatment if necessary. Too much emphasis cannot be placed upon how skilfully and painlessly the introduction of this electrode should be carried out. The patient is particularly apprehensive at the beginning of the first treatment, the prostate may be exceedingly tender and there may be some tenesmus with attempt to force the electrode out, but the effectiveness of the treatment depends upon how accurately the electrode is placed, so the electrical heat may be generated at the point desired. Upon not being shocked nor hurt, but, on the contrary, experiencing the soothing effects, the patient's morale is raised, and the second treatment will go more easily with better coöperation. The thermometer is introduced through the shaft of the electrode, which may be held in place with small sandbags above and below it, which also help to steady it.

The current is increased gradually, taking at least five minutes to arrive at a maximum temperature of 110° F., or 43.33° C. Above this temperature the patient complains of tenesmus and sacral pain, although the maximum temperature reached has been 112° F. (44.44° C.). The temperature registered in the thermometer is 1½ degrees less than that generated in the tissues. Even when the patient is tolerant of a high temperature, it is difficult to obtain, as the blood seems to carry the heat away faster after a temperature of 109 to 110° F. is reached. The milliamperemeter may vary from 1000 to 1800. Many patients may not be able to tolerate this temperature at first, but most will be able to bear it if it is gradually attained. In some, however, the tolerance will not be that high, and in these the patients' statements must be given as much weight as the thermometer in the prostatic electrode.

The treatment should extend over a period of 40 minutes to 1 hour or longer, daily, or even twice a day until the acute symptoms disappear.

Catheterization may have to be carried out for retention of urine and should be done under the strictest aseptic conditions, using a catheter which will cause the least amount of trauma, even a woven

While this may present itself as marked periurethral infiltration, a large percentage undergo suppuration with the formation of an abscess with persistent urethral fistula, or a persistence of the gonococcus in the follicles causes recurrence of the acute urethritis. Diathermy is very useful in checking the inflammation and preventing abscess formation, and if a persistent urethral fistula be present with demonstrable organisms, in eradicating the gonococci and aiding in a speedy closure of the fistula with abatement of the urethritis. Should an abscess form, diathermy is contraindicated and surgical drainage instituted.

If the *inflammation is confined to* the *penile urethra, two small tin* electrodes are employed, with the smaller one, which should be just of sufficient size to cover the affected area, placed on the posterior surface, the larger electrode directly opposite on the anterior surface, and both strapped in place with adhesive. Usually, not more than 200 to 300 ma. are required, which is repeated daily for at least an hour (Figs. 2, 3).

In cases of periurethritis involving the perineum, an electrode is fitted over the inflamed area on the perineum, and the block tin plate is used as the other electrode, employing not more than 800 to 1200 ma. of current.

We have observed diathermy clear up these troublesome periurethral fistulas where older methods were of no avail. If pus forms, it must be drained surgically.

Acute Prostatitis

Diathermy is the treatment of choice in the management of acute prostatitis occurring either as a complication of an acute urethritis, or in that smaller group of cases where the infection is hematogenous from disease elsewhere—as influenza. It far surpasses the old time-honored methods of applying heat—namely, sitz baths and hot rectal douches—because the heat can be actively directed to the prostate with a higher temperature, which is more uniform, and over a longer length of time. It relieves the patient quickly of the distressing symptoms, including retention of urine, if that be present, and reduces the size of the prostate rapidly and thereby shortens the duration of the disease. Outside of a slight tenesmus, which may be present at the introduction of the prostatic electrode at the first treatment and *which usually disappears afterward*, it *has a distinct* soothing effect upon the patient. In accordance with accepted general surgical principles, if pus collects forming an abscess, prostatotomy is demanded. The older method of passing a sound through the urethra and rupturing the abscess with the hope that it will drain into the urethra is not looked upon with favor, but open operation with drainage established to keep from rupture into bladder or rectum.

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Catheterization may have to be carried out for retention of urine and should be done under the strictest aseptic conditions, using a catheter which will cause the least amount of trauma, even a woven

olivary-tipped or steel catheter if necessary, with plenty of lubrication. All other local forms of treatment should be stopped during an acute prostatitis. The same routine is carried out in an acute infection of the seminal vesicles.

Diathermy has produced remarkable results in our cases of acute prostatitis, and, when presenting themselves early enough for palliative treatment to be instituted, prostatic abscess is a rare termination. Often, for patients with acute prostatitis refusing to be hospitalized, and in institutions where diathermy cannot be carried out for one reason or another, hot rectal douches or hot sitz baths are advised several times daily.

Chronic Prostatitis

Chronic prostatitis may result as a termination of an acute prostatitis, or it may be the product of the insidious extension occurring in the majority of cases with an acute urethritis. It may or may not produce any symptoms, but with absorption it acts as a focus for a host of symptoms, which will not be relieved until a careful search reveals the prostate as an offending portal.

The time-honored routine treatment of chronic prostatitis with digital massage and total bladder irrigation, supplemented with sounds, overdilatation of the posterior urethra, bacterin and protein therapy, has not produced brilliant results either in a permanent cure or the rapidity with which it was accomplished. Indeed, in a minority of patients who present themselves with a chronic prostatitis, it may be impossible to get the gland in such a shape that the microscopic examination of the prostatic drop does not reveal pus, even though the symptoms may be entirely gone. When a patient asks at the beginning in what time he may expect a cure, the truthful answer of "Impossible to state" rarely satisfies, and yet anywhere from "two months to two years with the average of approximately eleven months" is even less gratifying.

Anything which tends to offer a better solution of this inaccessible infection is welcome, and diathermy has been offered as a means of shortening the duration of chronic prostatitis. It is carried out in the same manner as described under Acute Prostatitis, the treatment being given two or three times a week. Less distress is experienced upon the introduction of the electrode and the tenesmus is practically absent. At least 40-minute treatments should be given (Fig. 4).

The diagnosis of chronic prostatitis is made, first, upon the findings at rectal palpation of the prostate, and secondly, on the immediate examination under high-power microscopic field (⅙ objective) of the expressed secretions, with the white blood cell count of not more than 5 per field being regarded as normal. This examination is carried out, of co urse, before any treatment is instituted, but MacArthur advises t a "check-up" is not necessary between treatments,

which should be given in series; in fact, he states that patients who have been given prostatic massage before their diathermy treatment do not respond as well as those who had none. A patient should be given one or two series of eight or ten treatments each and then a "check-up" on the prostatic secretion and, if this be abnormal, the series repeated.

MacArthur reports very good results from diathermy in chronic prostatitis. Our results like many others are variable, being not nearly as striking as in the cases of acute prostatitis. In a few, diathermy produced a cure, the cell count dropping to normal and staying there

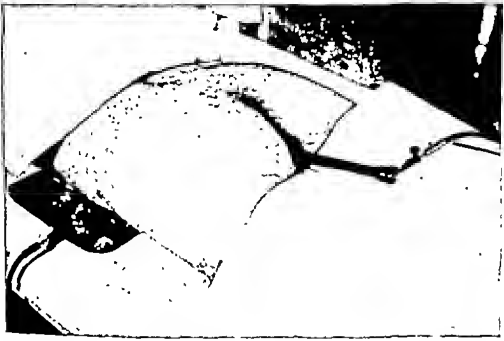

FIG. 4.—Diathermy in chronic prostatitis. Block tin electrode (6 by 8 in.) beneath abdomen. Thermometer in shaft of prostatic electrode registers 1½ degrees less than is generated in prostate. Prostatic electrode may be held firmly in place by sandbags.

after repeated examinations at lengthening intervals, but in a majority there has been no apparent beneficial result. It is true that the symptoms are relieved, but in other respects the condition is similar to that in the cases treated by digital massage, in other words, discouraging. Perhaps in our series of cases the treatments were not prolonged enough, and many of them had received previous prostatic massage. It was noted that careful attention to technical details gives better results. Again the economic conditions come up; most patients will not give the time necessary and have not the means to have diathermy carried out, neither do we have the physical accommodations demanded in treating all patients with chronic prostatitis with diathermy,

especially in hospital clinics. Therefore we reserve diathermy for those selected cases in which either by time, examination or economic condition it seems indicated.

Epididymitis

Epididymitis, a complication in about 15 to 20 per cent of cases of acute urethritis, with greater prevalence in hospital clinic cases, is included in the group of circumscribed areas of inflammation which are amenable to diathermy. The usual palliative treatment is rest in bed, with elevation by a bandage or strapping, application of heat or cold, free catharsis, forcing fluids, and perhaps protein injections. Local treatment must be stopped. This usually incapacitates the patient for from five to fourteen days, with the possibility that if the condition does not subside, incision and drainage may be necessitated. Some urologists do not believe in the palliative treatment but recommend immediate drainage, which results in a shorter hospital stay. We advocate palliative treatment except in the following conditions, which indicate that an epididymotomy should be done:

1. In the relief of pain.
2. Cases which do not subside promptly under palliative treatment.
3. Recurrent attacks.
4. Bilateral cases.
5. As a greater chance against sterility on the affected side.
6. To enable the patient to get on his feet sooner.

Diathermy has been recommended as a means of relieving the subjective symptoms and speedily returning the epididymis to normal. We have discarded the scrotal thermophore in favor of two block tin electrodes, cut to size and molded to fit the conditions, as described by MacArthur. As the epididymis lies under the posterior surface of the scrotum, the posterior electrode overlying this should be smaller than the anterior one. The electrodes are covered with soap lather or lubricating jelly and may be strapped with adhesive to hold them in place, held by the patient or supported by small sandbags (Fig. 5). The pressure applied on the upper electrode holds the lower electrode in place. The tolerance to heat varies greatly in patients. As there is no thermometer connection, the heat should be raised gradually, using from 750 to 800 ma., and the treatment carried on for at least 40 minutes to 1 hour after maximum temperature has been reached. At times it may be well to increase the heat until cutaneous discomfort is noticed and then reduce the current slightly so no unpleasant sensation accompanies the treatment. Treatments for a shorter time do not get the desired results and should be given daily until the condition improves.

MacArthur reports a series of 35 cases of epididymitis, 21 of which

were hospital patients. In these the average number of days before pain had subsided was 1.76, and the number of diathermy treatments required to reduce pain was 1.57. The average stay in the hospital was 6.52 days. The patients were not discharged until all the pain and tenderness had subsided, as had the swelling. These patients were all in condition to begin local treatment. Average number of diathermy treatments was 3.28. There were 14 cases in his private office; the length of time to relieve pain was 20 days, and the number of treatments was 1.9. Entire condition subsided in 6.7 days, with the average number of diathermy treatments being 6.1.

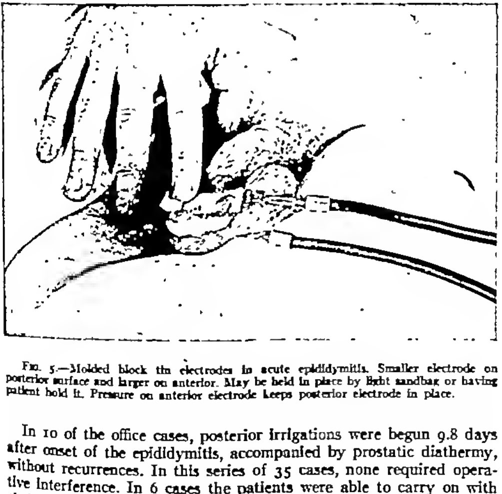

FIG. 5.—Molded block tin electrodes in acute epididymitis. Smaller electrode on posterior surface and larger on anterior. May be held in place by light sandbag or having patient hold it. Pressure on anterior electrode keeps posterior electrode in place.

In 10 of the office cases, posterior irrigations were begun 9.8 days after onset of the epididymitis, accompanied by prostatic diathermy, without recurrences. In this series of 35 cases, none required operative interference. In 6 cases the patients were able to carry on with their work after the first diathermy treatment, although one had a recurrence on the third day, which forced him to lay off for a day.

Our results are by no means comparable to this and may be recorded as indifferent. It is our experience that in a majority of cases the pain usually subsides as soon as the patient stays in bed with elevation of the epididymis. The diathermy treatment probably aided

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1. The local condition; the urethritis may be treated in the usual way or by diathermy, which will not produce results if a posterior involvement has occurred, in which case treatment may be directed to the prostate.
2. To the sterilization of the blood stream and what results may be accomplished by chemotherapy.
3. To the joint.

Here diathermy produces marked beneficial results, as the heat may be accurately generated. Various types of electrodes may be used, but the technic must be accurate to obtain results. The wire mesh electrodes have been advocated because they conform better to the irregularity of the joint. Where block tin molded electrodes are used, attention has to be given, if the heat is required through the joint, that the electrodes are of equal size; but where it is required that the heat be nearer one surface of a joint, the smaller electrode should be placed over that area and kept in place by strapping and sandbags.

The method of a cuff arrangement above and below the joint does not work out well, the current going almost through the superficial tissues. The various types of molded-to-fit block tin electrodes adapt themselves very well.

The treatments should be from 40 minutes to 1 hour daily until the patient is better, and the amount of current varies with the individual, ranging from 800 to 2000 ma. The tolerance of the patient is the best guide.

Chronic Inflammation of Sheath of Corpora Cavernosa

Chronic inflammation of the erectile tissues of the penis, especially of the corpora cavernosa, leads to areas of induration which, although painless, progress so that erection is difficult and impossible, or accomplished with a marked curvation of the penis. The condition may progress until these fibrous plaques become calcareous. The etiology is unknown but is often associated with a rheumatic or gouty diathesis. The majority of these patients have a chronic prostatitis also.

The treatment has been most unsatisfactory, with attention to any correction in metabolism, prostatic massage, internal administration of potassium iodide and often direct injections of fibrolysin, with the condition often becoming progressively worse.

We have tried diathermy in several of these cases, along with other mentioned treatment, and the results have been as good with other methods, if not better. If the fibrous plaques are formed as a result of chronic inflammation, then in diathermy we have the best means of combating this, if seen early enough. The electrodes of molded block tin are applied in the same manner as for periurethral conditions and, lasting 40 minutes, the treatments are given two or three times a

us in getting relief, but in accomplishing the rapid reduction of swelling and getting the patient out of the hospital in six days, we cannot record anything like the remarkable results as reported by MacArthur. It has been our belief that it is unwise to resume local treatment under a month, in cases of epididymitis treated palliatively, but where epididymotomy has been performed, local treatment can be started sooner. We advise all cases of epididymitis to stay in bed, preferably in the hospital where they can be watched and where it is possible to carry out diathermy as an adjunct to the routine treatment of elevation, forcing fluids and possibly nonspecific protein therapy.

A distressing funiculitis often accompanies the involvement of the epididymis, and this may be treated by placing one electrode over the globus minor of the epididymis, while the other is placed over the external abdominal ring. This permits heat to extend over the accessible portion of the vas and should be carried out as previously described.

The question arises, naturally, whether in those cases treated with diathermy, the testicular function of spermatogenesis is disturbed. MacArthur, attempting to answer this, was not definitely able to state at the time of his report but is of the opinion that it is not. There were 10 cases of epididymitis which were given from one to ten treatments of diathermy, after which operation was performed and a section of testis removed. In 6 of the 10 cases, the pathologic findings in the testes were so severe that spermatogenesis was lost, but this could readily be due to the intensity of the infection and not to the diathermy. In 2 of 10 cases (one of four treatments and one of six) both had active spermatogenesis. In a case of chronic bilateral epididymitis, in which it was either a case of doing a bilateral epididymectomy or treating with diathermy, the treatments were given to both epididymes, after which all the pain and swelling subsided. One month later, semen showed actively motile sperms and this was checked up in another similar case and motile sperms found. The consensus of opinion is that there is no permanent damage.

Diathermy should be withheld and epididymotomy employed when actual pus formation is present.

Arthritis

The acute arthritis, which occurs as a metastatic complication of acute gonorrheal urethritis, is a serious affair and demands prompt and efficient remedial measures, else the individual may be crippled for life. While nearly any joint may be affected, the larger joints as the knee, ankle, hip and elbow are mostly involved and it may be polyarticular. Synovitis and tenosynovitis may accompany it.

The treatment should be directed to three main issues:

to disturbances of micturition, mostly frequency and perhaps some pain at the end of urination. The urine is usually clear and free from pus. The experienced cystoscopist will have no difficulty in diagnosis, and the polyps are quickly and easily destroyed by electrocoagulation. A large block tin electrode, 6 by 8 inches, is placed beneath the patient's buttocks, then with a No. 6 French Bugbee electrode in the cystoscope, the tip is placed in contact with the base of the polyp and with a low current it is quickly destroyed. Much better vision and manipulation may be obtained by having a continuous stream of boric solution flowing to distend the urethra. The current should not be too strong, not nearly as much as is used in destroying tumors of the bladder, as the posterior urethra is more sensitive and the patient does not tolerate this as well. We usually employ local anesthesia only, which is obtained by placing a tablet consisting of one grain of novocaine in the posterior urethra with a tablet depositor, which is especially designed for that purpose. If the patient is nervous and apprehensive, a hypodermic injection of morphine and atropine is given one-half hour before the operation, or some other sedative like sodium amytal may be used. Caudal anesthesia has been used and, where the occasion demands it, general anesthesia, where due caution must be taken in regard to electric sparks and ether if used.

Usually such growths can be destroyed at one sitting, and the patient is advised to return in several weeks for observation.

The same treatment is applicable and the response equally as good in similar diseases of the posterior urethra, as tumors of the verumontanum, hypertrophy of the verumontanum and granulation tissue in the posterior urethra. We have used this bipolar method of electrocoagulation in cases of varices or bleeding coming from the posterior urethra, in some instances following topical application of silver nitrate, when nothing else would control the marked hemorrhage; with continuous dilatation of the urethra, the bleeding point is sought, and, placing the tip of the Bugbee electrode on it, electrocoagulation is accomplished with a low current.

The interest of urologists has been revived recently in the handling of patients suffering from what has been called a median bar, which may be either fibrous or glandular. The bladder neck may become sclerosed and contracted by fibrous scar tissue, and this may be termed *fibrous obstruction* and may follow prostatectomy. The first work and attempt at correction was done by Guthrie just one hundred years ago, and it was stated by him that only those bars or obstructions which were not associated with glandular enlargement were amenable to the instrumentation he devised before the days of direct vision of these contractures. This method fell into disuse and remained dormant until Young brought forth his punch, with which pieces were bitten out of the bladder neck at various angles until the obstruction was removed. The great danger in this procedure was hemorrhage, and it has been our custom to do a suprapubic cystotomy and bite out

week. As this disease is slowly progressive, it may be some time before definite signs indicate that even this treatment is of no avail.

Enuresis

Enuresis in children is essentially a functional disease with a natural tendency toward cessation at puberty. Often a careful physical examination in male children will disclose some alteration in the urine, irritation about the meatus or glans, stricture calculus or spina bifida occulta, the correction of which will arrest this condition. Curtailing the fluid intake after 4 P.M. and the placing of a large wooden pill box or wooden spool in the lumbar region with a string that may be tied around the waist, which will shift the child when an attempt is made to sleep on the back, are often sufficient to effect a cessation of the enuresis. Of the remaining cases, we have found by a cystoscopic examination, mostly under a general anesthetic, that the prostatic urethra is usually markedly congested, with an enlargement and engorgement of the verumontanum. With the tip of the No. 6 French Bugbee electrode placed on the verumontanum through the cystoscope and a large electrode beneath the buttocks, the bipolar current is turned on and the verumontanum electrocoagulated.

We have seen a number of young boys where this treatment was highly effective, enuresis not being resumed after a single treatment.

Urethra

There are several conditions involving the urethra, particularly the posterior urethra, in which electrosurgery produces brilliant results, that in the past have been difficult to accomplish with the older methods of sounds, overdilatation of the posterior urethra and the topical applications with silver nitrate.

The general practitioner is usually not equipped nor has he the ability to make cystoscopic examinations, but he should bear in mind that patients complaining of some disturbance of micturition, such as frequency or burning, or possibly terminal hematuria, may have some pathologic change in the posterior urethra, which will account for this even though the cystoscopic examination fails to reveal any abnormality in the bladder or kidneys. The expert makes it a part of the routine examination, after completing the inspection of the bladder, thoroughly to investigate the urethra. This is best carried out with the cysto-urethroscope or convex sheath and having a continuous stream of boric solution flowing all the time to distend the urethra. This makes a better instrument for diagnostic purposes, at least, than the ordinary urethroscope, with either the curved posterior tube or straight tube, and permits a thorough inspection of the entire urethra.

At times small polyps or polypoid formations are found at the vesical neck or just outside in the prostatic urethra, which give rise

Collings has always emphasized that this electrical excisioo is only applicable in fibrous bars and he does not recommeod its use io the glandular type. The knife-like electrode is introduced througb the modified McCarthy foroblique panendoscope, and the excisioo carried out under direct vision, which is aided by cootinuous irrigations throughout the operation.

The patient sbould be bospitalized and the operatioo carried out under caudal anesthesia, or, as we have ascertained in the last few cases, local anesthesia, the drug being given directiy into the bar by a long needle attachment to the bypodermic syringe. A large block tin electrode is placed under the buttocks for an inactive electrode.

The author states: "The cysto-urethroscope is passed into the bladder. With the bladder partially distended, and the inflow and outflow of water regulated, the electrode is eogaged upoo the bar at 6 o'clock. The current is turned on and marked bubbling is noted. The protein molecules are exploded by jostling of the high-frequency oscillations. The urethroscope and electrode are slowly pulled back *en masse* until the verumontanum appears. A white furrow about 2 mm. deep is seen. The instrument, with the electrode in the furrow, is then pushed forward and through the bladder neck. Working back and forth in this manner the groove is gradually widened and deepened. Cut until you see the last obstructing fibrous band has been sawed into. One can, from the verumootanum, look down a deep valley (perhaps 1.5 cm. deep) and see the base of the bladder. Persist in your efforts until you are satisfied the patient has a wide open bladder oeck. If this is accomplished, the patient will be relieved. We were all timid at first and cut too littie. Do not be afraid of the rectum—it is still 1.5 cm. away (as determined oo the cadaver).

"By turning the knife blade sideways ooe engages the blade on the bladder oeck at 5 o'clock. Cut downward and backward until the intervening tissue is whittied away. This procedure is repeated at 7 o'clock.

"The operation can be slowly and precisely performed in about 20 minutes.

"There is only a minimal amount of heat peoetration beyond the line of incision. By microscopic examination we have found tissue destruction extends only 1 to 2 mm. beyond the cut."

The one drawback to this procedure has been the necessity of an apparatus to deliver the cutting current. The ordinary diathermy or high-frequency machioe will not deliver this current. We now employ in our clinic the same Westinghouse machine as used in the modified Caulk punch operatioo. For the visual excision of fibrous bars, this instrument is effective, but it is not suitable for the glandular types of obstruction, neither is it as rapid nor has it as much latitude as the modified Caulk, which formerly carried this out without direct vision.

Stern conceived the idea of a loop excisor, and in 1926 started a movement whicb has been termed variously as *transurethral prostatic*

the pieces under direct vision, so the hemorrhage, if there were any, could be controlled at that time.

Recently, some new instruments have been offered for the correction of this obstruction, some of which employ direct vision, and from being relegated to a palliative procedure, a wild enthusiasm has swept along to such an extent that not only are the fibrotic median bars attacked but resection of glandular hypertrophy, so that in a large urban hospital no radical prostatectomy has been carried out during the past year.

Formerly, this method was advised in those obstructions of the vesical neck due to a fibrous median-bar formation where the glandular element was not the primary factor; in contractions of the neck following prostatectomy; as a palliative procedure in those cases which for one reason or another could not stand a radical operation and where enough tissue could be removed to prevent retention; and lastly, in cases of carcinoma of the prostate for the relief of retention, with no expectation of a curative process.

Caulk has devised an ingenious punch to correct obstructions at the bladder neck. The instrument is an electrical adaptation of the Young punch and, while observation of the portion to be excised may be carried out prior to the excision, the actual punching is carried out without visual aid. Recently there has been added a visual system to this punch. The patient should be hospitalized. The anesthesia may be caudal or local, employing the long needle attachment to the syringe, and the operation may be carried out painlessly with the exception of the point when the tissue is just being completely excised. A large block tin plate is placed beneath the buttocks for the inactive electrode. The author states that the heat generated does not destroy this removed tissue and a histopathologic section may be made where diagnosis is desired. He has further stated, recently, that not only are the fibrous contractures at the bladder neck amenable to this operation but he is employing it in the glandular types of obstruction, namely, hypertrophy, cutting sections at various angles to relieve the obstruction, following which there was noticed a recession in the size of the gland.

Birdsall has modified the Caulk punch by enlarging the fenestra and employing a cutting current as delivered by the portable endotherm, a spark gap machine of the Westinghouse Company, which combines medical and surgical diathermy with a cutting current. The hemorrhage is minimal, and a Robinson catheter, No. 24 French, is tied in for forty-eight hours. There are some patients whose urethra will not take this No. 28 French instrument; general contraindications will be discussed later.

Collings has offered a method of electrical excision of these bars by utilizing the cutting current. The oscillations of the cutting current are some fourteen or fifteen times faster per second than the fulgurating high frequency suggested by Beer and require a special apparatus.

only factors to be considered in the end-results, even if the remainder of the gland undergoes retrogressive changes.

BLADDER

With the introduction of the high-frequency current presented to urology by Dr. Edwin Beer, in 1910, the treatment of benign tumors of the bladder was completely revised. The poor results following open operation were so discouraging that the profession welcomed this new electrosurgical procedure and today it is the accepted mode of treatment. It is essential that the correct diagnosis be made, and the expert cystoscopist is able in well over 90 per cent of cases to differentiate between a noninfiltrating benign tumor and an infiltrating malignant tumor. Failure to respond to electrocoagulation is suggestive that the growth is malignant.

Beer advised the monopolar current, but the bipolar current is used mostly now. A large 6 by 8 inch block tin electrode is placed beneath the patient's buttocks to act as an inactive electrode. The cystoscope with the Bugbee electrode is passed into the bladder, and the tip of the electrode is placed at the base of the narrow pedicle and the papilloma destroyed. Where the base cannot be seen, the electrode is placed against this projecting mass, but the tumor is destroyed more quickly when the base can be attacked. When the current, which may be used stronger here than in the posterior urethra, is turned on, a stream of bubbles arises and pieces of tissue may seem to burst. The speed of destruction depends upon the size of the tumor, but most papillomas can be destroyed in several sittings. As there is a marked tendency to recurrence, approximately 40 per cent, the patient is requested to report at three months' intervals for the first year, six months' intervals the second year and yearly thereafter to check up against recurrence.

When the tumor discovered in the bladder is considered malignant, the question of the form of treatment is most important, first, in that the prognosis depends upon how early and accurately the diagnosis is made, and secondly, as there is no universally accepted treatment and each case is a study in itself, the procedure employed being dependent on many factors.

There is no accepted pathologic classification of bladder tumors, and the cystoscopist should rely upon the clinical classification of malignancy. The expert cystoscopist is able to give a better opinion than anyone else, notwithstanding that biopsy has been advised in doubtful cases, despite the warning that this may disseminate the growth faster. Papillomas are considered potentially malignant and are liable to undergo malignant degeneration if not destroyed. The cystoscopist divides the malignant tumors into two types—noninfiltrating and infiltrating.

Upon the family physician rests the responsibility of early diagnosis

resection and *punch prostatectomy*. Davis proved the practicability of loop resection by reporting in 1931 a series of 100 cases with no fatalities. Marked improvement had been made in the machines producing the cutting current and in the switching devices to the coagulation current for the arrest of hemorrhage. McCarthy, alive to its possibilities, proceeded along scientific lines to produce a unit nearer to perfection. Enlisting engineering aid, the "McCarthy surgical unit" has been offered as the last word in the tube-set high-frequency machine. The controversy has not been definitely settled as to whether the tube-set or a spark-gap machine is the better type. It is claimed that the tube-set has many advantages over the spark-gap and none of its disadvantages, due to its uniformly continuous oscillation, which makes cutting smoother. From the practical standpoint in our clinic, the cutting and coagulation current, as produced from a portable spark-gap endotherm, is very effective.

A special bakelite sheath is provided for the panendoscope, and the resection carried out under direct vision. Multiple bites are necessary, and usually the first bite is the largest. The patient should have a permanent catheter for several days.

The same careful examination and preparation are as necessary for these patients as for those who are candidates for a radical operation, where renal and cardiovascular tests besides others have to reach a certain standard before the patient qualifies. Most of the instruments used for resection are of fairly large caliber (No. 28 French), certain urethras tolerate such manipulation poorly and urethral fever results as after any other instrumentation; this should be carefully guarded against, as well as ascending infection. We have seen several cases of stricture formation follow, particularly near the meatus. While the procedure has been described as bloodless, it may be far from this at times. With new improvements in switching from the cutting to the coagulating current, much hemorrhage is controlled with the coagulating electrode and this should be carried out after each bite is removed.

It takes considerable manipulative skill to become a resectionist, even if one is more than fairly familiar with the cystoscope, and it has been discarded by some after several disastrous attempts. We have had and seen certain cases where radical operation had to be carried out where attempts at resection had failed for one reason or another.

Not every prostatic enlargement is suitable for resection, and cases carefully selected will give the best results. Certain it is that those prostatics with intravesical complications such as stone, tumor or diverticulum are not suitable candidates. Very large intravesical and large intra-urethral enlargements are difficult to handle and often impossible.

Sufficient time has not elapsed for ultimate evaluation of this procedure, for recovery and relieving of residual urine are not the

generally regarded as hopeless. In certain clinics the papillary carcinomas are destroyed by cystoscopic electrocoagulation, and radium is applied by a cystoscopic carrier, with results comparable to other means. Again, radium has been applied in all cases of noninfiltrating and infiltrating growths, and results comparable with surgery have been obtained in the earlier cases; attacking those advanced cases where surgery is contraindicated, it has relieved the patient of symptoms and extended the duration of life.

Surgical diathermy has been advised for carcinoma of the prostate, attacking by the perineal and also suprapubic routes, but has not found much favor. The results of treatment of carcinoma of the prostate are even more discouraging than that of carcinoma of the bladder. We used this method on one patient, who died of a severe hemorrhage from the prostate three days after operation.

The best results in carcinoma of the prostate have been in those cases which were not suspicioned prior to operation, nor suspected at operation, but with the diagnosis made by histopathologic section after complete enucleation.

Those cases which are suspected at operation, but where the gland has been completely removed and diagnosed definitely in the laboratory, are next in line. Postoperative roentgen-ray therapy is advised. Where the diagnosis is suspected prior to operation, radical removal is not usually advised, except by Young, who recommends extracapsular prostatectomy if the gland has not broken over the capsule.

Radium has been advised in these cases and may be applied in the form of seeds, either by exposing the gland suprapubically and then perineally or by implanting through a needle in the perineum. The roentgen ray will disclose the exact position of these implanted seeds. The histopathologic diagnosis may be made by aspirating some of the prostatic tissue through a special needle. Roentgenograms should be made of the bones and lungs to rule out metastasis before any treatment.

The roentgen ray will often relieve the distressing pain in the back and legs, which may be the first subjective symptom. The prognosis is bad.

Ureter

The treatment for stenosis of the ureteral orifice formerly was incision, which was liable to be attended with severe bleeding and which in a few reported cases necessitated cystotomy. This also applied to those cases where there was a distinct bulging of the last centimeter of the ureter due to the occlusion by a stone.

The ureteral orifice can now be slit for any reason by surgical diathermy through the cystoscope. With the patient prepared as for cystoscopic electrocoagulation, a special electrode with a small Y-shaped tip is introduced into the orifice, and, with the bipolar current, the roof of the ureter is incised for a short distance. This may be accom-

in these cases of malignant tumor of the bladder. With the cardinal symptom of often painless hematuria, the patient consults his advisor, who too often complacently administers a urinary antiseptic and is readily satisfied if the hematuria ceases in a day or two. Insistence of cystoscopic examination at this time would do more for the patient's prognosis than our most effective treatment later on.

With a sessile type of tumor, the best information with regard to what extent infiltration has taken place is obtained by an aerocystogram and a cystogram, which we employ routinely. A roentgenologic examination should be made of the bones of the pelvis and spine, and of the lungs for possible metastasis, which is late and rare in those carcinomas affecting the bladder only, but common in those cases associated with carcinoma of the prostate.

Leading authorities agree that the best results are obtained by radical surgery in those selected early cases where the tumor is favorably situated for excision, with or without resection of the ureter. Total cystectomy with transplantation of the ureters has a high mortality except in the hands of the most expert.

In those cases which are either too extensive for resection or unfavorably situated but yet not too far advanced and without visible evidence of metastasis, we advise a combination of a suprapubic cystotomy and destruction of the tumor by diathermy. General anesthesia is employed, and an inactive electrode, 6 by 8 inches, is placed under the sacrum. The active electrode is selected from several sizes of flat disks and screwed on the handle, and the strong current is controlled by a foot switch. Due precaution must be taken if ether is used as an anesthetic, on account of the sparking by the machine. After cystotomy, the active electrode is introduced directly on the tumor and it is destroyed by electrocoagulation. The charred tissue may be removed by a curet, and the destruction is carried out wide of the tumor tissue. Little attention is paid to the ureteral orifices, and usually there is no retention on the involved side. In a series of cases treated in this manner a few years ago, we implanted radium in the destroyed base, but the results were no better than in those who did not receive radium, so we discontinued it. Roentgen-ray therapy should precede and follow this procedure. This combination of surgery and diathermy is not designed primarily to be curative, but it will relieve patients of distressing symptoms, improve their condition, in some cases allow them to return to their occupation and add a few years to their life. We have a few cases where the diagnosis was confirmed by histopathologic section that are living and well five to eight years after operation.

In those advanced cases, any treatment other than palliative has a tendency to hasten their end, so we usually resort to roentgen-ray therapy and cystotomy when retention occurs.

The so-called papillary carcinoma or noninfiltrating type responds better to treatment than the infiltrating type; in fact, the latter is

did not commence until they had exposed themselves to sunlight, following which healing was rapid.

In the bilateral cases, surgery is usually contraindicated and heliotherapy has been advised. Diathermy has been advocated for palliative purposes, but mostly frowned upon. In some cases there is a persistent and distressing cystitis which resists all palliative measures. Beer states that fulguration of these ulcerations and granulations does produce temporary relief, and reapplications of the current may be necessary.

Genital tuberculosis, primary in the epididymis and going on to suppuration, is amenable to surgery, and epididymectomy is indicated. There is a marked tendency to become bilateral. It should be borne in mind that the infection in the epididymis may be secondary to that in the kidney, and the kidneys ruled out before any surgical procedure is carried out. Diathermy is contraindicated. Tuberculin given therapeutically in the form of bacillus emulsion has proved beneficial in cases where focal, local and general reaction has been avoided.

Testicle

Following the suggestion of Ewing who stated, in 1911, that all tumors of the testicle should be regarded as teratomas or mixed tumors, we advise radical surgery as soon as diagnosis is made. Mostly in young adults in the third decade, the condition is highly malignant and the prognosis bad, with metastasis occurring mostly to retroperitoneal lymph nodes within a year, whether or not a radical resection of the lymph nodes up to the lumbar group is carried out. The Memorial Hospital of New York City reports encouraging results with the application of radium, hut these have not been found elsewhere.

panied with the Bugbee electrode if one is expert. Slitting of the lower vesical portion of the ureter will often permit the prompt passage of stones, which have been lodged at this narrowest portion of the ureter.

Medical diathermy has been recommended for patients with stones in the ureter or kidney, but it is not much used. As heat often relieves these conditions, diathermy should be more efficacious, but, in our experience, those patients with a ureteral colic require morphine hypodermically and will tolerate nothing during the attack of severe pain.

Kidney

We have had little experience with diathermy in renal conditions, but it has been advocated in all those cases where heat was formerly employed. As the kidney is closer to the posterior surface, the smaller electrode, 4 inches square, is placed over the kidney region, and the larger, 10 by 8 inches, is placed on the upper abdomen. The current is increased gradually with the amperage averaging 1000 to 2000. This should be over a period of 40 minutes.

In tumors of the kidney, diathermy is contraindicated. Early diagnosis as made by chromo-ureteroscopy, pyeloscopy, retrograde or intravenous urography indicates surgery with preoperative and postoperative roentgen-ray therapy. In those larger hypernephromas which are regarded as inoperable, roentgen-ray therapy has a marked tendency to relieve pain, stop hematuria and produce a marked diminution in the size of the tumor.

Roentgen-ray therapy is indicated also in the mixed tumors of the kidney seen in children and where removal cannot be accomplished.

Genito-urinary Tuberculosis

Long clinical experience has placed genito-urinary tuberculosis, with the primary seat in the kidney, upon a surgical basis. Always secondary to tuberculosis elsewhere, it is spoken of as primary in the particular region of the genito-urinary tract that it affects first, usually the kidney and epididymis. While theoretically tuberculosis may begin as a bilateral affair, it clinically develops as a unilateral affair, and, when diagnosis of surgical kidney is made, nephrectomy should be carried out. In certain selected, bilateral cases when one kidney is only slightly impaired and its fellow more so, the better kidney has improved after nephrectomy of the worse one.

As the condition is systemic, the patient is by no means cured after nephrectomy. There is a marked tendency to breaking down of the wound. A general antituberculosis régime is advocated—rest, good food and fresh air. Under the last head, heliotherapy carefully carried out has a distinct place, and it has been reported by Bumpus that some patients volunteered the information that healing of the wound

CHAPTER TWENTY-TWO

PHYSICAL AGENTS IN TREATMENT OF GYNECOLOGIC CONDITIONS

GRANT E. WARD, M.D., F.A.C.S.

SECTION I

DIATHERMY

History.—The employment of high-frequency currents for medical or surgical purposes has come to us through a long process of development, brought about by the untiring, gratuitous, coöperative labors of a group of physicists and medical and surgical investigators, to all of whom a debt of deep gratitude is due. As one reviews the history it becomes evident that advances were often simultaneous and quite independent in widely separated areas, making it difficult at times to assign priority in the construction of apparatus and improvements in technic. Elsewhere the history and physics of high-frequency currents and their biophysical effects are given in greater detail than is possible or necessary here; suffice it to define a few terms for clarity.

Definitions.—Diathermy, in the simplest and most exact sense, means "to heat through." From the word alone no electrical connection is evident, but, since its incipiency, diathermy has been used to designate that form of heat produced within the living tissues by the passage of a high-frequency current through them, when this heat is not destructive but within physiologic limits. Within the last few years radio-tube apparatus have been devised for diathermy treatments, which create an electromagnetic field between two large plates so that when the patient is placed within this field a rise in general body temperature to 105 or 106° F. results.

Electrosurgery, on the other hand, is the utilization of properly regulated high-frequency electric currents in the performance of surgical operations, as in making incisions in normal tissue, excising diseased areas, or in the desiccation (dehydration) or coagulation destruction. The therapeutic agent is the electrically developed lethal heat within the tissues themselves, in contradistinction to the physiologic heat of diathermy.

Endothermy is a name coined many years ago but not emphasized or enlarged upon until the notable work of George A. Wyeth in 1924. Some authorities claim for Germany the origin of this word;

Obviously with strong currents higher temperatures are generated; a happy balance between voltage nnd amperage must be obtained to generate the proper amount of heat without shocking and pain. As the application is prolonged the temperature rises to a point where the conduction and radiation disperse the heat as rapidly as it is formed and a state of equilibrium exists, the given current maintaining the same temperature, as a rule, and any increase in the current strength increasing the heat proportionally.

Snch conditions prevail in a homogeneous medium, but in the body certain variations occur due to the different densities of the body tissues through which the currents pass. The denser tissues offer increased resistance, allowing less current to flow through with correspondingly less temperature rise. Tissues vary in density from greatest to least as follows: bone, cartilage, ligaments, fascia, skin, muscle and fat. Heat is also dispersed by radiation and by conduction of the blood stream.

High-frequency currents are known to travel on the surface of metal conductors. That this also holds in the case of organic substances was shown by Bettman and Crohn, who worked with bologna sausage, observing that the highest temperature registered at the periphery, just beneath the skin of the sausage. This then brings about a difference of opinion from the theoretic aspect described above. From a practical standpoint, however, investigation reveals increases in deep temperatures during the application of high-frequency currents, dependent on the strength of current and balance between voltage and amperage; in other words, in spite of the variations in tissue structures and densities, temperatures in deeper organs, as the lungs, liver and pelvic organs, are moderately raised by diathermy currents, the depth of this temperature and its exact location being determined by the size, shape and location of the electrodes. Bettman and Crohn further demonstrated that when ngar-agar is the homogeneous conducting medinm, temperatures occurred midway between equal-sized electrodes or nearer the smaller of two electrodes of different area. If a piece of bone or other nonconducting substance is placed in the center of the agar, the electromagnetic waves are bent around the bone, and a concentration of current with a greater rise in temperature appears at the periphery of the bone. E. A. Weinberg and the author (unpublished) have confirmed these observations in living dogs by inserting a clinical thermometer in a hole bored in the bone of the foreleg and another in the surrounding soft parts, while diathermy was applied, higher temperature readings being obtained in the soft parts next to the bone.

Diseases.—In discussing the use of diathermy in gynecology, the writer will refer freely to the work of Corbus and O'Conor, and Thomas H. Cherry and others (see bibliography). In spite of some theoretic and laboratory evidence to the contrary, heat penetration is

others, that Mr. Kurt Stoye, a physicist, was the first to utilize it. Endothermy literally means "heat from within." Wyeth calls electrodesiccation "monoterminal endothermy"; electrocoagulation, "biterminal endothermy"; and the cutting current, "endotherm knife." Further differentiation of electrodesiccation, electrocoagulation and cutting is given under "electrosurgery."

The term "uniterminal" refers to one cable connection between the small active electrode and the instrument, the patient acting as a condenser, disseminating the current, which then returns to the generator. "Biterminal" infers two direct connections between patient and apparatus: (1) a small active electrode, concentrating the current to raise the local temperature within physiologic limits (diathermy) or above that lethal to the tissues (electrosurgery), and (2) a large, inactive or plate electrode in close contact with the patient's skin at a point distant from the treated area. Frequently, two equal electrodes are employed to raise uniformly the temperature of a part of the body or extremity. In medical literature the words "bipolar" and "monopolar" were extensively used, but as there is no polarity to a high-frequency current such terms are erroneous.

Physiology.—The physiology of heat is thoroughly discussed in Volume I. Diathermy heat is, because of its mode of production, much more penetrating than that from any other source. As high-frequency currents pass through the tissues, heat develops within them, differing in this way from the radiation and conduction heat of hot instruments applied to the surface of the body, as hot-water bottles, hot baths, the Paquelin or electric cautery, etc. Painstaking clinical and laboratory researches have proved that this heat penetrates to practically any depth of the body and raises the temperature of deep-seated organs. Therapeutic temperatures of 108° F. can be obtained in the urethra and rectum, and 111° F. in the cervix. With this elevation there is *pari passu* an increase in the oral temperature from 0.5 to 1.0 degree. Such temperatures produce the familiar physiologic effects of dilatation of blood vessels and increased circulation, and have sedative effects upon the nerve endings and relaxation of the muscles. These effects bring the body defense mechanisms, leukocytosis and swelling of the tissues with exudation of blood plasma, to fight disease or promote repair processes. Certain authors claim a most important function to be the germicidal action upon invading organisms, particularly the gonococcus, noted for its susceptibility to moderately high temperatures, but more recent investigations disprove this assumption. The above facts place diathermy among the standard treatments of gynecologic diseases.

The degree of heat applied is under the direct control of the operator, being varied by (1) size of the electrodes, (2) densities of the tissues treated, (3) amount of current utilized, and (4) duration of application.

and relief of pain from reduction of pressure upon nerve filaments. Likewise in turn, a rapid absorption of the exudate follows the increased blood flow, together with mobilization of the body's natural defense resources. Since the inflamed adnexa usually prolapse into the culdesac of Douglas, Cherry performed a series of experiments to ascertain temperature rises here. With an abdominal electrode measuring 18 by 12.5 cm. and a vaginal electrode, the exposed surface of which measured 5 by 3 cm., the temperature of the culdesac was elevated to 48° C., while the vaginal temperature registered 44° C. For this treatment a special electrode (Fig. 1) is made with a hole drilled near the surface for the exposure of the thermometer bulb to the vaginal tissues. Through this contrivance, by adding two degrees to the temperature registered in the vaginal tissues, he estimated the approximate degree of heat in the adnexa and, with such a technic, treated a series of 100 cases with disease of the tubes or ovaries, or both.

In spite of the fact that electrotherapists and authorities on physiotherapy have continually warned against using diathermy in pus-containing cavities with no outlet for drainage, it seems reasonable to Cherry to assume that if gonococci were the exciting factor producing such a condition and if a penetration of the diseased structure by a heat of 46° C. could be obtained, the causal agent would be destroyed, with incidental reduction in the inflammation. Such specific heat effects are questioned by Scheffey and others. Improvement by this reduction in infection and the active hyperemia was realized in a large percentage of Cherry's 100 cases. Diagnosis was made either by obtaining positive smears from the urethra and cervix in most of the patients or, in others with negative smears, by numerous pus cells and a history of subacute or chronic urethritis, endocervicitis, skenitis or bartholinitis. The degrees of pelvic involvement varied from small, thickened, tender adnexa to large pus tubes or tubo-ovarian abscesses entirely filling the pelvis. Twenty-three of the patients had adnexal disease without masses and 77 had adnexal disease with masses.

The results in this series of cases are so remarkable that a few figures are of interest. In all there was practically instant relief of pain. The masses disappeared entirely in 18 of the 77 and were reduced in size in 14 more, a total improvement of 32, or 41.5 per cent. The complete disappearance of the inflammatory tumor seemed more apt to occur where there was an initial attack of adnexal infection, while in the chronic ones the reduction in size and subsidence of the acute symptoms made the lesions practically innocuous, although remaining palpable, requiring more prolonged diathermy. Forty-nine of the 77 were entirely relieved of symptoms, operations being unnecessary or refused; the other 28 were operated on. At operation the masses were found to be hyperemic, soft, edematous and smooth, and the adhesions vascular and thin in contradistinction to the thickened, fibrous type so frequently encountered in chronic pelvic in-

regulated by varying the size and shape of electrodes and their points of application. In this manner, therapeutic temperatures are applied to the urethra, vagina, cervix and even the adnexa, when they are the seat of salpingitis or tubo-ovarian abscesses. The amount of heat tolerated by the normal tissue, without destruction or coagulation, probably varies between 55 and 58° C. Cherry applied diathermy through the abdomen of a dog, heating the bladder and rectum to 52° C. without histopathologic changes. He also developed 55° C. in the human cervix for 10 minutes, without any gross tissue changes.

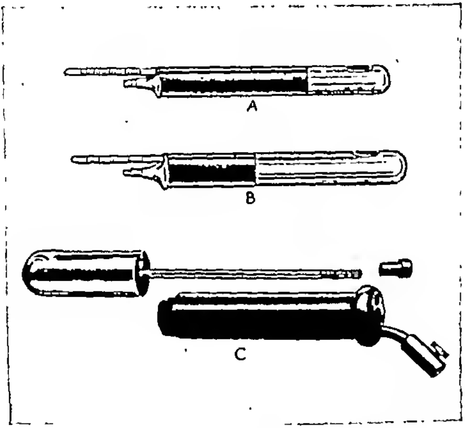

FIG. 1.—Cherry's vaginal electrodes. Active metal surface comes in contact with cervical and vaginal tissues. An open window connects with a canal which passes through upper surface of electrode its entire length. This allows introduction of thermometer, with bulb in contact with vaginal tissues, giving accurate measurements of heat dosage. A, electrode used in the treatment of cervix and adnexa. B, electrode with larger active surface for application to urethra, utilized at same treatment for cervix and adnexa. C, Cherry's recently improved model.

It is well known that living tissue dies at 60° C., temperature also lethal to the gonococcus, which is vulnerable to as low a temperature as 42° C. for ten minutes.

Diathermy treatment of pelvic infections causes hyperemia and quickened circulation, with reduction in stasis in the engorged vessels

and relief of pain from reduction of pressure upon nerve filaments. Likewise in turn, a rapid absorption of the exudate follows the increased blood flow, together with mobilization of the body's natural defense resources. Since the inflamed adnexa usually prolapse into the culdesac of Douglas, Cherry performed a series of experiments to ascertain temperature rises here. With an abdominal electrode measuring 18 by 12.5 cm. and a vaginal electrode, the exposed surface of which measured 5 by 3 cm., the temperature of the culdesac was elevated to 48° C., while the vaginal temperature registered 44° C. For this treatment a special electrode (Fig. 1) is made with a hole drilled near the surface for the exposure of the thermometer bulb to the vaginal tissues. Through this contrivance, by adding two degrees to the temperature registered in the vaginal tissues, he estimated the approximate degree of heat in the adnexa and, with such a technic, treated a series of 100 cases with disease of the tubes or ovaries, or both.

In spite of the fact that electrotherapists and authorities on physiotherapy have continually warned against using diathermy in pus-containing cavities with no outlet for drainage, it seems reasonable to Cherry to assume that if gonococci were the exciting factor producing such a condition and if a penetration of the diseased structure by a heat of 46° C. could be obtained, the causal agent would be destroyed, with incidental reduction in the inflammation. Such specific heat effects are questioned by Scheffey and others. Improvement by this reduction in infection and the active hyperemia was realized in a large percentage of Cherry's 100 cases. Diagnosis was made either by obtaining positive smears from the urethra and cervix in most of the patients or, in others with negative smears, by numerous pus cells and a history of subacute or chronic urethritis, endocervicitis, skenitis or bartholinitis. The degrees of pelvic involvement varied from small, thickened, tender adnexa to large pus tubes or tubo-ovarian abscesses entirely filling the pelvis. Twenty-three of the patients had adnexal disease without masses and 77 had adnexal disease with masses.

The results in this series of cases are so remarkable that a few figures are of interest. In all there was practically instant relief of pain. The masses disappeared entirely in 18 of the 77 and were reduced in size in 14 more, a total improvement of 32, or 41.5 per cent. The complete disappearance of the inflammatory tumor seemed more apt to occur where there was an initial attack of adnexal infection, while in the chronic ones the reduction in size and subsidence of the acute symptoms made the lesions practically innocuous, although remaining palpable, requiring more prolonged diathermy. Forty-nine of the 77 were entirely relieved of symptoms, operations being unnecessary or refused; the other 28 were operated on. At operation the masses were found to be hyperemic, soft, edematous and smooth, and the adhesions vascular and thin in contradistinction to the thickened, fibrous type so frequently encountered in chronic pelvic in-

flammatory disease. Consequently, operation was greatly facilitated, the tumors being readily delivered with a minimum of trauma to surrounding structures. The contents had been reduced by the treatment to a thin, watery, straw-colored fluid instead of the usual thick, creamy, purulent exudate, and all cultures were negative. The lessened operative trauma made convalescence free from discomfort and pain, vomiting and distention. Only two wound infections occurred—7.7 per cent as against 30 per cent wound infection in a large series that

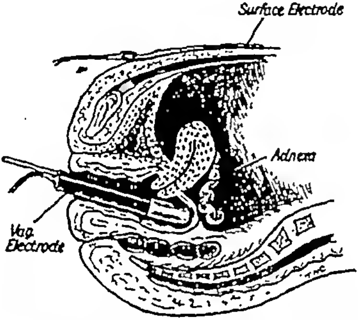

FIG. 2.—Application of Cherry's vaginal electrode "A" for cervical and adnexal infection.

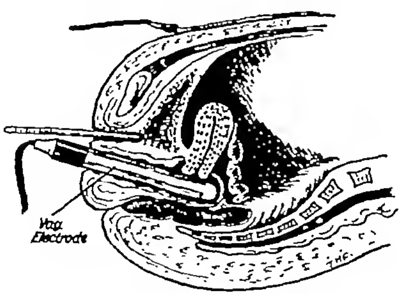

FIG. 3.—Cherry's electrode "B" in place for treatment of urethra, cervix and adnexa.

had no preoperative diathermy treatment. In summary, Cherry says: "I would venture the assertion that diathermy is probably the most satisfactory available agent for the conservative treatment of pelvic *infections due to the gonococcus. It relieves pain, diminishes the pelvic* masses and aids in complete resolution. Used as a preoperative therapeutic measure, it will eliminate many of the technical difficulties in the removal of large pelvic masses and thereby contributes a smoother convalescence. Incidentally the percentage of postoperative wound infections is lessened." Further investigation and verification of these results should be carried out in our larger clinics.

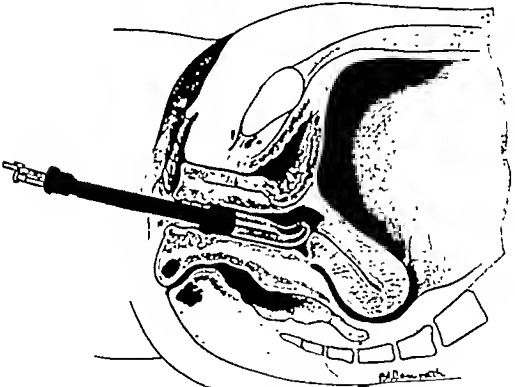

Fig. 4.—Chapman electrode in place treating cervix and adnexa. (Courtesy of Journal of Radiology.)

There are data at present insufficient to state whether pelvic infections other than those of gonococcal origin, such as follow parturition or abortion, will yield so readily to diathermy. The little available evidence seems to point in the adverse direction. The streptococcus, staphylococcus or colon bacillus requires a temperature of 58 to 60° C. for destruction. Diathermy, through the pelvis, raises the temperature insufficiently to have any specific effect on these bacteria and, on the contrary, seems to aggravate the symptoms. The degrees of heat developed produce a suitable cultural temperature in which these

bacteria thrive, pelvic peritonitis and other complications following; the diagnosis of the organism is therefore extremely important.

TECHNIC OF DIATHERMY APPLICATION IN THE PELVIS.—The pelvic application of diathermy is carried out in one of several ways: (1) Two large equal electrodes are placed one on the abdomen and one on the sacrum, with a consequent temperature increase midway between the electrodes. Inasmuch as the temperature is to be concentrated as near as possible in the culdesac and around the cervix, the abdomino-vaginal application is more practical. (2) Several special electrodes have been devised for application to the cervix and the vaginal vault,

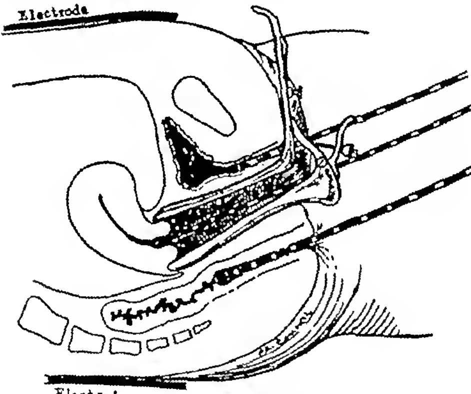

FIG. 5.—Roblee electrode No. 1—a bivalve Graves speculum placed in an upside-down position, the handle acting as a binding post for connection of the electric terminal. Thermometers in urethra, rectum and cervix, measuring temperatures of 108 to 109° F. (42.22 to 42.78° C.) in rectum and vagina and 102.5 to 103° F. (39.16 to 39.44° C.).

this being the *nearest approach to the prolapsed diseased adnexa* in the culdesac. (3) Another method is the abdominorectal application, giving less favorable results. The accompanying illustrations (*Figs.* 2 to 8) show better than description the methods of applying the electrodes. In the treatment of gonorrheal urethritis the Corbus electrode (*Fig.* 9) is applied through the urethra with a pad on the abdomen, or beneath the sacrum.

In the abdominovaginal or abdomino-urethral application a thermometer is contained in the active electrode, as a guide to the temperature rise. Accurate approximation of the electrodes, both on the surface and in the cavity treated, is important. The large pad electrode, usually consisting of block tin, is covered with green soap for accurate contact and held firmly on the abdomen by belt or sand bag —not necessary for sacral application, as then the patient lies on the electrode, assuring even contact with the skin. Any irregularities on

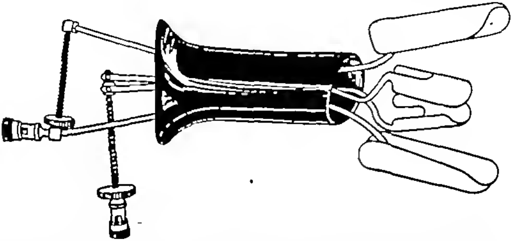

FIG. 6.—Roblee electrode No. 2 with four overlapping blades. This electrode is placed in vagina as a hollow cylinder and then dilated to bring two blades' forceful contact against the cervix and the other two against vaginal walls, the longest posterior blade pressing well back into culdesac. When used with the lumbosacral or belt electrode, temperatures of 109 to 110° F (42.78 to 43.33° C.) were recorded for urethra and rectum and 103 to 104° F. (39.44 to 40° C.) for the cervix.

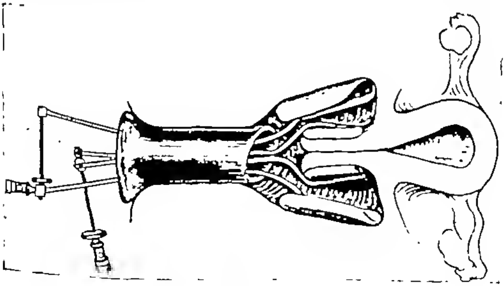

FIG. 7.—Roblee electrode No. 2 in place

bacteria thrive, pelvic peritonitis and other complications following; the diagnosis of the organism is therefore extremely important.

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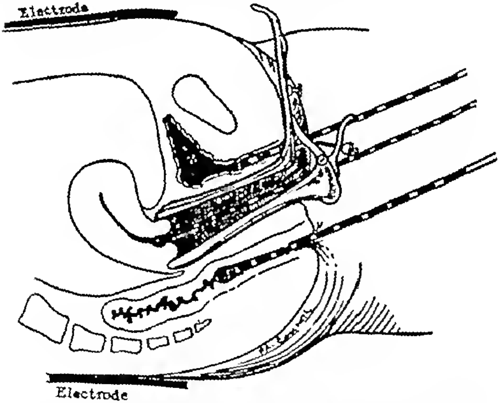

FIG. 5.—Roblee electrode No. 1—a bivalve Graves speculum placed in an upside-down position, the handle acting as a binding post for connection of the electric terminal. Thermometers in urethra, rectum and cervix, measuring temperatures of 108 to 109° F. (42.22 to 42.78° C.) in rectum and vagina and 102.5 to 103° F. (39.16 to 39.44° C.).

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the temperature rises above this, the current is reduced to maintain the desired degree of heat. The treatment is continued for from 15 to 30 minutes and repeated at three to five day intervals, until improvement becomes stationary. Endocervicitis, usually coexistent with the adnexal disease, receives treatment while the pelvis is diathermized. After the intrapelvic disease has cleared up, any lingering chronic infection requires electrocoagulation, to be described in a subsequent paragraph.

Diathermy for acute gonorrheal urethritis is not firmly established but should be mentioned because of beneficial results in certain cases. Treatment is by the use of the Corbus thermophore (Fig. 9), a small, round instrument with a tapering, metal tip an inch and a half to two inches in length, carrying a thermometer in its center. Application is directly within the urethra, with a large inactive pad beneath the buttocks. The urethral orifice is cleansed with boric solution, and the sterilized thermophore inserted and held in place by a suitable clamp fastened to the table. Treatment is continued for from 15 to 30 minutes at a temperature of 41° C. (800 to 1,000 ma. of current) and repeated in from three to five days until urethral discharge has subsided. The current is increased slowly, taking about eight minutes to reach the desired milliamperage and temperature.

The destruction of infection in Skene's glands requires a true surgical procedure but is discussed here because of its close association with gonorrheal infections of the other pelvic organs. The periurethral tissues are cleansed with a mild antiseptic, and 2 per cent novocaine injected at four points about the urethra. A needle-like electrode, carrying either a fairly strong uniterminal current of rather high amperage or a moderately strong biterminal current, is inserted the full length of the gland until a whitish, coagulated area appears about the needle. This insures complete destruction of the infection and the epithelial lining of the gland. Argyrol, 10 per cent, is applied to the urethra about twice a week until healing occurs in two to three weeks.

The literature contains many reports of the use of diathermy in the treatment of *dysmenorrhea*, with highly satisfactory results, the increased blood flow accounting for the improvement. It is also stated that *amenorrhea*, when due to hypoplasia of the endometrium, is greatly benefited by the dilatation of blood vessels (Theilhaber). Guthmann, I. de Ruben and others vouch for the symptomatic improvement in *vesical affections*, particularly cystitis. Here the muscular spasm is relieved and painful urination or incontinence eliminated.

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the surface cause uneven concentration of the current with uncomfortable sparking or, in some, a burn. The electrodes are now connected to the machine and the current turned on, beginning around 200 to 250 ma. and slowly increasing until vaginal temperature reaches 42 or 43° C. This usually requires 1,000 to 1,500 ma. of current. If

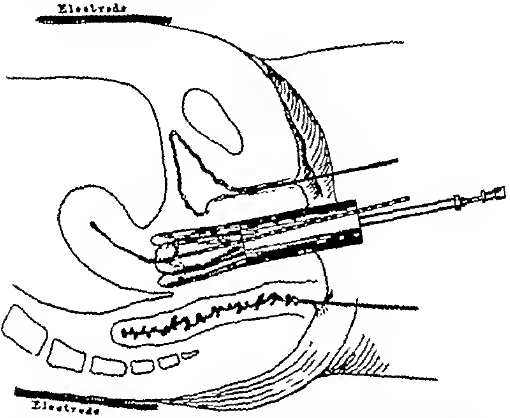

FIG. 8.—Zener cervicovaginal electrode, No. 1, with four blades closing about cervix, concentrating heat in cervical canal and immediate parametrium without material loss in rectum and urethra, giving temperatures of 109 to 110° F. (42.78 to 43.33° C.) in cervix and urethra and 108 to 109° F. (42.22 to 42.78° C.) in rectum.

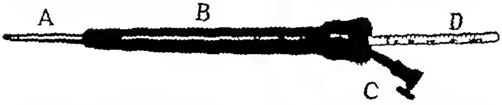

FIG. 9.—Corbus thermophore consisting of thin nickel silver shell, A, closed at one end, measuring 5 mm. in diameter. A hard-rubber shield, B, measures 15 cm. by 1 cm. and allows extension of 4 cm. for insertion in the cervix or urethra. C, insulated terminal provided for attachment of cable supplying current. D, thermometer inserted to full depth of shell and readings taken from exposed portion. It has been found that great accuracy is necessary in constructing the instrument to insure its proper performance. Any small diathermy machine capable of supplying 800 to 1,000 ma. will produce heat enough to apply the thermophore. (Courtesy of Corbus and O'Conor, and Bruce Publishing Co.)

The first electrosurgical current was uniterminal—only one wire and one electrode connecting the patient with the generator. This "fulguration" current is of high voltage (potential) from a long spark gap and correspondingly low amperage (volume of current). The effective heat penetration of such current is limited, and soon its inefficiency for the destruction of any large amount of diseased tissue was realized. During years of development the voltage has been reduced by shortening the spark gap and altering the transformer, there being, *pari passu*, a perceptible increase in amperage. Higher frequencies were obtained with the shorter spark gap and still higher frequencies with the introduction of a multiple gap (Clark). The present-day currents are much more powerful than the earlier ones, destroying readily to a depth of 2 or 3 mm. in a short time, longer contact coagulating tissue to 1.5 cm. from the point of application when necessary. Along with this development of such powerful currents came the advent of electrosurgical cutting, first popularized by George A. Wyeth, so useful in sealing capillaries and lymph vessels as the incision is made.

Electrodesiccation

Electrodesiccation, as its name implies, is the dehydration of tissues by the heat developed within them during the passage of a high-frequency current. William L. Clark of Philadelphia, first to employ this term, uses it to designate that form of tissue-destruction caused by the passage of a uniterminal current of high amperage and low voltage (short spark gap). The cells are devoid of water (dehydrated) and appear elongated and shriveled under the microscope, the cell outline, however, being still visible. These changes are most marked in the heat-sensitive tumor cells.

The author studied the histologic changes effected by electrosurgical currents, in an effort to confirm Clark's work, and found that by varying the strength (amperage and voltage) and time of application, electrodesiccation could be obtained with either a uniterminal or biterminal current, much less time being required, however, for desiccation with the stronger biterminal current. In the literature, however, the term *desiccation* usually means the dehydration of tissues with a uniterminal current; that is, a current delivered to the patient through one electrode and one wire from the generator, the patient dissipating the current through the air back to its source.

Electrocoagulation

Electrocoagulation was first employed by E. Doyen of Paris about 1907, who enlarged upon the fulguration of Reviere, Pozzi and de Keating Hart by changing the electrical connections to the patient and by using more powerful transformers. Two wires connect the generator to the patient, one to a large pad beneath the back or but-

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SECTION II

ELECTROSURGERY

The use of high-frequency, oscillating electric currents as physical agents in performing any surgical operation is called "electrosurgery" in contradistinction to the usual surgery with the cold, sharp scalpel. Under "diathermy" a careful differentiation between it and electrosurgery is made. There are three electrosurgical currents, designated by their effects, desiccation (dehydration), coagulation and cutting. Electrosurgical currents are alternating in character, i.e., their direction of flow changes many times per second, and because these alternations are so numerous, usually 750,000 to 1,000,000 and at times 3,000,000 per second, the term *high frequency* is used to distinguish the current from the low frequency commercial currents of ordinarily 60 cycles, or 120 oscillations per second. The higher the oscillations, the smoother the current, with less muscular response and more effective application. These currents are of varying voltage and amperage, depending upon the needs.

homogeneous mass. The tumor cells, being more sensitive to heat, are affected first, forming large masses of granular débris within a hyalinized stroma; the stroma is more resistant to heat and slowly destroyed. In the usual specimens the connective-tissue stroma is seen as a fused translucent eosin-staining matrix of hyalinized material with partially destroyed nuclei scattered here and there. The blood vessels contain clots adhering to the heat-damaged wall. Coagulation may be obtained by a heavy uniterminal current of high amperage and applied for a considerable length of time, as compared to that necessary for desiccation. Usually, however, electrocoagulation is accomplished with a biterminal current generating high destructive temperatures, the tissues actually boiling in their own juices. This type of destruction is used for large tumors, whereas desiccation is sufficient for small, benign and malignant ones.

Electrosurgical Cutting

Electrosurgical cutting currents were first experimented with by Lee de Forest in 1908 and later by others, but without practical application until the thoroughgoing studies of George A. Wyeth, who has so aptly popularized this important surgical adjuvant. Tissues are easily and quickly severed by currents of higher frequency than that required for desiccation or coagulation, for example, 1,500,000 to 2,000,000 oscillations or more per second. For the smoothest cutting the oscillations should be as nearly equal as possible, notably, those from radio tubes which are undamped, that is, of equally sustained oscillations, without rest periods between them. Currents from a spark-gap generator are damped; that is, the oscillations are in chains, each oscillation in the chain being consecutively shorter than the previous one until the zero line is reached with a rest period following, allowing the current to pile up on each side of the gap until sufficiently powerful to jump it, when oscillations again occur with similarly decreasing height. (Desiccation and coagulation currents are usually of the damped variety.) Primary union following electrosurgical cutting demands less penetration than for coagulation or desiccation and is obtained by lower voltage and higher frequency. With a carefully balanced cutting current, incisions are made with as little as one-tenth of a millimeter destruction of tissue at the skin edge (Ward, using Wyeth's endotherm, where radio tubes are source of current). By increasing the strength of the current, any desired amount of penetration from this superficial effect up to that necessary to stop bleeding from small vessels is obtainable, and with spark-gap generators on to flashing currents causing destruction to one or two millimeters on each side of the incision. With such a current, of course, primary union is usually impossible, these currents being for the removal of massive, ulcerating malignancy, where wound closure is im-

tocks and the other to the active, surgical electrode, which in his practice was a small disk. At present, most surgeons employ either a needle, a flat blade with or without a sharp cutting edge, a blunt rod, a small ball, a wire loop or other form of small instrument, increasing the current density at the point of contact (Figs. 10, 11). Electrocoagulation, as its name implies, results from the actual heat coagulation of the tissue-protein, which appears under the microscope as a

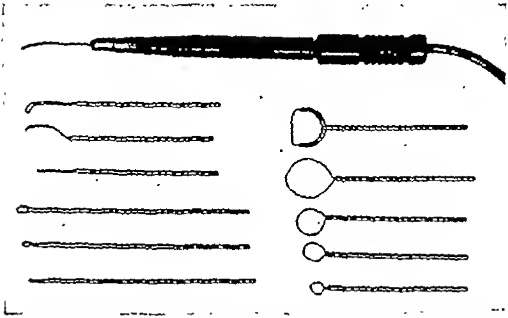

FIG. 10.—Assortment of active electrodes: curved, flat, diminutive knife blades, convenient in resecting tumors difficult of approach; varying sizes of electrosurgical loops for scalloping out otherwise inaccessible tumors; coagulating ball electrodes; adjustable handle

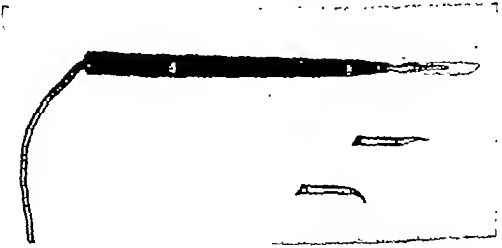

FIG. 11.—Groff electrosurgical knife with interchangeable Bard-Parker blades

Robbins and Leabury describe the way to treat *chancroids:* a 25 per cent solution of copper sulphate in distilled water is applied for a few minutes, after which the lesion is desiccated well beyond the diseased margin. A light antiseptic dressing is placed over the sore and in a few days the foul sloughing ulcer exhibits a healthy granulating surface.

Pruritus vulvae, a most distressing and resistant disease, calls for a thorough search of the general physical condition and study of the blood chemistry to exclude constitutional causes. If none is found, electrosurgery comes to the relief of the suffering patient. The current strength and the method of application depend entirely upon the extent and depth of the disease. Superficial and less extensive involvement calls for the active, point electrode carrying a uniterminal current to be played over the surface until white desiccation appears. Moderately deep-seated diseases require that the needle touch or slightly penetrate the skin. The duration of application may be shortened when desired by using a flat, disk-like active electrode, treating larger areas at a time. This instrument is placed in direct contact with the skin until blanching occurs and then moved to an adjacent area. The after-care is a daily application of an antiseptic salve, such as 1 per cent yellow oxide of mercury or mercurochrome, until the desiccated tissue comes away to be replaced by normal epithelium.

In the more extensive cases, where the entire vulva and adjacent portions of the thigh or the perianal region are involved, more radical procedures are necessary. The cutting current is efficacious in excising the disease, with a wide margin in normal tissue, the edges being brought together with suture for primary union, when a fine current is used. Stronger currents, advisable when ulceration is present suggestive of malignancy, prevent primary union, the wounds healing by granulation. The skin and subcutaneous fat are so redundant that contracture of large wounds is not disfiguring, the edges being gradually pulled toward each other, limiting the amount of cicatrix which is always soft following electrosurgery. Occasionally after extensive operations, skin graft is necessary.

Cysts of Bartholin's glands call for removal of the entire wall, which prior to the advent of electrosurgery meant resection, usually under a general anesthetic, and considerable hospitalization. Several years ago, the author, while treating a case of ranula, hit upon the idea of destroying the epithelial lining with a uniterminal current, allowing the walls to fall together and heal by granulation. Such a splendid result was obtained that cysts and epithelial-lined cavities in other parts of the body have been successfully attacked in the same way. Small Bartholin-gland cysts are treated under local anesthetic in the office; larger ones usually require general anesthetic and short hospitalization. Whether the cyst be small or large, the technic is the same (Fig. 12), a strong cutting current opening the cyst and evacuating the contents. The epithelial lining is then thoroughly destroyed by a strong desic-

possible anyway. The sterile, dry coagulum, 1 to 2 mm. thick, prevents reimplantation or dissemination of cells.

In electrosurgical cutting a tiny arc should be maintained between the electrode and the tissues; pressure obliterating this arc disseminates the current so rapidly that cutting is slow and with much destruction. A new sense has to be learned by the surgeon—that of very delicate application of his electrode and rapid drawing of it over or through the tissues.

Application of Electrosurgery

Vulva and Vagina.—*Small benign tumors* are promptly destroyed by a desiccating current under local anesthesia. The method of anesthesia is optional, and the needle electrode, carrying a current of proper strength for the size of the tumor, is first played around the edges to cut off any dissemination of cells, should there be suspicion of early malignant change. The rest of the tumor is then dehydrated, curetted away with a small suitable curet and the base redesiccated to sufficient depth, destroying all cells which may be growing out into normal tissue.

A method of indirect application is sometimes employed where the patient grasps a large, tubular electrode or lies on an "inactive" pad. The operator then touches the diseased area with a needle, the current passing through it and the operator, who acts as a condenser. Heat is developed within the lesion, where the current is concentrated as in the direct method, with the same destructive effect. The dehydrated tissue is then curetted away as before and the current reapplied if indicated.

An antiseptic solution applied with a small cotton applicator insures against subsequent infection of this now sterile scab. I prefer Scott's mercurochrome,* Bohlman's gentian † or 7 per cent iodine.

For small lesions no dressing is necessary. Larger or multiple ones require the usual surgical-wound care during the healing period, which lasts from ten days to three weeks, depending upon the extent.

Sinclair Tousey describes painless removal of small skin tumors without anesthesia. Pedunculated ones are clamped at the base and the active electrode applied to the distal portion, the current (uniterminal or biterminal) only traversing the insensitive growth. If the growth is flat, a curved pair of forceps (Tousey-Baffle) is so placed that the tumor rests between its jaws, the active electrode then being applied to the center. With a biterminal current, the forceps completes the circuit through the operator, who is, in turn, connected to the machine; if the current is uniterminal the forceps is grounded through the operator.

* Scott's mercurochrome: mercurochrome, 2 Gm.; distilled water, 35 cc.; 95% alcohol, 55 cc.; acetone, 10 cc.

† Bohlman's gentian: gentian violet, 2 Gm.; distilled water, 35 cc.; 95% alcohol, 55 cc.; acetone, 10 cc.

ciated with rapid healing where tissues are loose and freely movable. A thorough application of radium should be given first, then under general anesthesia the involved area removed with a wide margin of safety, using the strongest cutting current, and the base of the wound resterilized by coagulating to a depth of two or three millimeters, eradicating all outgrowing cells and those spilled during the operation. The coagulum is now painted with an antiseptic solution, such as previously mentioned, and the wound kept well protected with the proper dressings. The sterile coagulum comes away in from one to two weeks, allowing the development of rapidly growing granulations for epithelialization. By combining these two therapeutic agents, complete eradication of the disease is more certain, and, in addition, electrosurgical removal counteracts the sclerosing action of the radium on the vessels, permitting more rapid healing or earlier plastic repair and softer scars.

Urethra.—Electrosurgery furnishes a quick, sure method of removal of the most painful urethral condition—*caruncle*. Except in highly nervous patients the operation is performed under local anesthesia in the office. A one or two per cent procaine solution injected on all sides blocks the urethra. The smaller caruncles are simply desiccated down to the urethral wall and allowed to slough away; larger ones are grasped with forceps and carefully resected with a fine cutting current. Frequently, redundant urethral mucosa, likewise eradicated by electrosurgery, is mistaken for caruncle. The redundant mucosa is dissected away under local anesthesia, or desiccated back to normal tissue. Corbus and O'Conor describe a method of utilizing a narrow, flat electrode, placed consecutively in four radial positions, destroying a small area of mucous membrane in each of the four quadrants of the urethral orifice. As healing and shrinking take place the redundant mucosa is drawn into normal position.

Urethral polyps, usually small, are readily removed under local anesthesia with a desiccating current, thoroughly dehydrating the polyp which sloughs away in a few days. Should the polyp be large or malignant, its base can be cut through with a cutting current, removing the tumor *en masse*, and then the base coagulated.

Following all of these urethral operations, healing takes place in from ten days to two weeks, the patient experiencing very little pain except in the exceptional case. Local application of procaine or cocaine ointment will relieve all pain. Usually, however, postoperative treatment is limited to ordinary cleansing measures.

Cervix.—*Chronic endocervicitis* is the most common disease which confronts the gynecologist. It is now recognized that the usual medical treatment of chemical antiseptics, tampons, etc., is only palliative, except where the infection is superficial and has not penetrated to the base of the glands. To cure the infection which over a long period of

cating or coagulating current, as the occasion demands, usually applied on a blunt or ball electrode, complete and accurate penetration into every nook and crevice of the collapsed wall being imperative. The cavity is then painted with Bohlman's gentian, packed with iodoform gauze and dry dressings applied. Daily application of the gentian and iodoform gauze is continued until the slough separates, the gentian then being discontinued, allowing healthy granulations to fill in and close the defect.

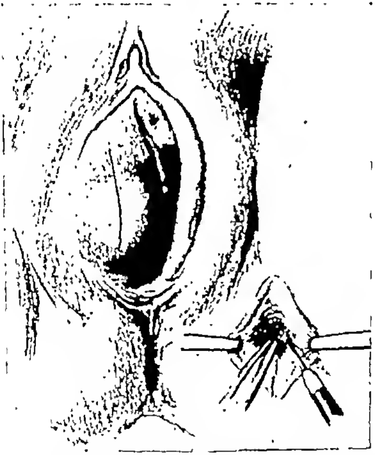

FIG. 12—Electrosurgical incision of Bartholin's gland cyst. Insert—Coagulation of epithelial lining.

In treating accessible *malignancy* such excellent results are obtained by radium therapy that it must always be considered. Many malignant tumors of the vulva and vagina are completely eradicated in the earlier stages by the thorough application of radium. (See Sect. III.) It is especially desirable in the treatment of vaginal malignancy, where exceptional improvement occurs, surgical resection even with high-frequency currents being technically difficult and fraught with marked distortion. Electrosurgical resection of tumors of the vulva is asso-

heals in another two or three weeks, during which time inspection should be made once or twice and also within the next month or two to watch for any possible constriction of the canal. Should any adhesions begin to develop, they are readily broken up by the insertion of a small instrument or a cotton applicator.

Mortimer N. Hyams describes a clever method of "conization of the cervix" for destruction and removal of infected cervical tissue. After inserting the customary vaginal speculum with the patient in the dorsal position, and cleaning out any residual leukorrhea, the cervical canal is anesthetized by placing a small crystal of cocaine in it. An applicator saturated with 85 per cent cocaine solution is introduced and allowed to remain for five minutes, and an inactive, wet metal electrode strapped on the abdomen, the patient being directed to make

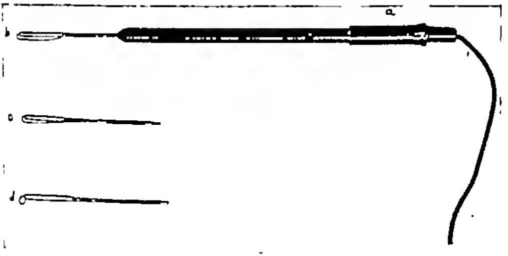

FIG. 13.—Hyam's electrode for conization of cervix.
(a). Swivel handle, allowing rotation of electrode without interference from attached wire.
(b and c). Porcelain tips with various sizes of wire arcs.
(d). Loop for removing bits of infected tissue high up in canal.

firm compression on the pad with hands, assuring accurate contact and distracting her attention from the operator. The active electrode (Fig. 13) is a fine tungsten wire stretched over a silicon tube one and one-half inches long and properly attached at each end for the conduction of the current. The silicon tube and tungsten wire are held in a long suitable handle having a swivel joint for attachment of the cord from the generator. The tungsten wire describes an arc of about one-eighth inch at its widest portion, conforming to the normal contour of the cervical canal, which is fusiform, or spindle shaped. Several sizes of electrodes are available with varying widths of the arc, as well as others for biopsy and destruction in difficult angles of the

time has burrowed deeply into the racemose glands, forming large cysts full of pus, and has extended high up to the internal os, no method of treatment short of some form of surgery is sufficient to eradicate thoroughly the disease in its deepest hiding places. Various scalpel operations have been devised which leave the cervix free of disease, but subsequent labors are complicated by the reduced cervix following amputation, allowing miscarriages, or by the dense scar tissue following other procedures, making labor prolonged and difficult. Thorough destruction of the infected tissue, with either the actual cautery or electrosurgical current, clears the condition and leaves a soft, pliable, normal-appearing cervix. Occasionally a thin diaphragm obstructs the canal, requiring a dilatation in the office on one or two subsequent occasions.

Less extensive involvement can be taken care of satisfactorily in the office, particularly if the patients are coöperative and will stand the moderate discomfort. The inactive pad is strapped to the thigh or placed beneath the buttocks, and the vagina and cervix are painted with a local anesthetic, preferably 20 per cent procaine, as it is safe from sequelae; with a nervous patient, a short nitrous oxide anesthesia is given. In all cautery or electrosurgical operations on the cervix, it is well to protect the mucosa and vulva with gauze saturated with boric acid or normal salt solution, thus preventing the steam or acid smoke, in the case of cautery, from irritating the tissues. A long, thin, preferably needle-like or slightly flattened, electrode is inserted into the canal up to the internal os, and the biterminal coagulation current turned on, destroying the tissues for two or three millimeters on all sides; deeper destruction is obtained by longer exposures. Radial applications are made and nabothian cysts punctured, evacuated and sterilized.

In dealing with extensive infection the technic is similar, only carried deeper into the tissues, requiring anesthesia and hospitalization. The coagulated tissue comes away gradually, and usually the cervix is quite clean and granulating at the end of two weeks. It goes without saying that this coagulum, although sterilized by the current, will in a short time contain large numbers of bacteria. It is important to keep down this secondary overgrowth and thus control the amount and odor of the leukorrhea by topical application of an antiseptic solution, such as Scott's mercurochrome or Bohlman's gentian, two or three times a week, together with alkaline or saline douches on alternate days.

Electrocoagulation is more rapid and deeper than cauterization with the actual hot cautery, necessitating care against too much slough, a possible source of secondary hemorrhage. When I first began this work I witnessed two or three such hemorrhages due apparently to deep sloughing, but by carefully controlling the current this complication has been overcome.

After the sloughing is complete, in one to two weeks, the cervix

short-circuiting through the vaginal mucosa or vulva. The snare is snugly placed about the pedicle and gradually tightened through it as a strong cutting current is applied to the handle, sealing blood vessels and lymphatics as the polyp drops off. The base may then be more deeply coagulated if necessary by reapplying the current through a long straight or curved electrode.

Robert Fowler has described a unique method of an indirect snare with the patient on an autocondensation pad attached to the uniterminal Oudin circuit of the electrosurgical generator; a snare is placed about the pedicle in the usual manner, the current passing through the operator, who acts as a condenser.

Submucous myomas which have descended through the cervical canal are readily attacked with an electrosurgical snare as just described. Should the pedicle be long, a strong cutting current is required on a cutting edge or narrow flat electrode to dissect into the uterine cavity, removing any lingering pieces. Not infrequently, submucous myomas do not present at the external os, being found on routine examination of the uterine cavity. Kelly has had several experiences of splitting the anterior lip of the cervix with a cutting current and resecting these otherwise unapproachable tumors. Electrosurgery greatly reduces the amount of hemorrhage when these tumors because of their size require piecemeal removal.

The differential diagnosis of cervical ulcers, a constant and important problem, is greatly simplified by biopsy, now available as an office procedure, placing at the disposal of every gynecologist the early diagnosis of cancer. It is a simple routine to take out a piece of suspicious tissue for microscopic examination, with a wire loop in a suitable handle as an active electrode carrying a strong cutting current. The edges of the specimen will be coagulated to a limited degree, the center furnishing enough unaltered tissue for adequate study. Any large vessel which may bleed is easily controlled by the application of the coagulating current on a blunt electrode.

Electrosurgical treatment of *carcinoma* of the cervix is only an adjuvant to irradiation and should never be relied upon as the only method of destruction of malignancy in this area. Radium is now well recognized as the method *par excellence* for the treatment of malignancy of the cervix. (See Section III.) However, electrosurgery acts as an aid in the removal of excessive growth, permitting the radium application to outlying posts of the growth's advancement. In spite of recent extensive public education regarding cancer, we are constantly confronted with patients in advanced stages of the disease with complete destruction of the cervix, or with a great cauliflower mass filling the vagina. Here the cauliflower growth is removed with an electrosurgical loop or snare, or the cervix amputated flush with the vaginal vault. This is by no means a routine measure, as the smaller lesions are readily treated by irradiation alone.

canal. A proper cutting current with sufficient coagulation to control bleeding is necessary.

The active electrode is inserted into the canal and the current turned on. As the wire cuts through the tissue the electrode is rotated throughout an axis of 360 degrees, cutting out a cone of cervical mucosa and opening all infected glands for drainage. If necessary the instrument may be reintroduced, removing all diseased tissue. Any bleeding from large vessels is easily controlled by applying the coagulation current on a blunt electrode. Infected nabothian cysts present beyond the area removed are punctured with a needle carrying a coagulating current. This wells out the contents, sterilizing the cavity and eradicating the infection.

A gray slough will be found filling the cervical canal about the end of the fourth day, and on the seventh day the canal is much smaller and granulating nicely. Between the second and third weeks the cervix is almost normal with several small, unhealed areas here and there. At the end of the fourth week healing is usually complete. Hyams advised against vaginal douches as unnecessary because of the small amount of sloughing and consequent leukorrheal discharge. He claims that conization is especially convenient for the treatment of ambulatory patients, relieving symptoms by the removal of the infected mucous membrane and opening of the glands, thereby facilitating drainage and reducing congestion deeper in the cervix. Since no muscular tissue is removed, the cervix remains functionally normal and subsequent parturition is unhampered. Diseased tissue is removed to any desired depth by repeating the procedure as often as advisable.

Electrosurgery is the method *par excellence* for removing *papillomas* of the cervix and pedunculated fibroids presenting at the os. Usually papillomas are sufficiently large to require a general anesthetic; occasionally small ones can be removed in the office either by electrodesiccation or electrocoagulation, or by cutting the pedicle with an electrosurgical current. For the larger ones the usual preparations are required as for any other vaginal or cervical operations. After adequate exposure, traction is made on the polyp and the pedicle then severed with a strong cutting current and its base coagulated, destroying any possible lingering cells, assuring against recurrence. Should the pedicle originate high in the canal or uterine cavity, the cervix is split anteriorly (Kelly), using a fine cutting current, a strong one preventing primary union after closing the incision. With the canal laid widely open, the pedicle is outlined and cut across with a stronger current.

Another unique method of attacking cervical polyps is with an electrosurgical snare, first described by William L. Clark for the removal of bladder tumors through a suprapubic incision. Since then it has been employed for pedunculated tumors in almost every accessible part of the body. An ordinary tonsil snare is satisfactory, although special instruments have been devised embracing the same general principles. The shank is insulated with rubber tubing, preventing

sarcoma of the uterus, located in the left broad ligament, displacing the uterus to the right and elongating the uterine cavity to twenty centimeters and bulging into the vagina, causing profuse and alarming hemorrhage. Thinking the tumor a myoma, preparations were made for vaginal removal. Incision in the vaginal vault exposed a highly vascular, soft, pliable and encapsulated sarcoma, from which hemorrhage was so brisk that operation had to be abandoned with the patient in a collapsed stage, but not before the mass had been excavated by a combination of electric scalloping and morecellement. This then permitted application of radium up into the tumor, otherwise impossible.

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Intramural and subserous fibroids are also removed with a strong electrosurgical cutting current through an abdominal incision, bleeding being distinctly lessened, reducing the shock. In this manner operations for the removal of large myomas, otherwise impossible, save the uterus for normal function and often for subsequent pregnancy.

Extensive *transabdominal pelvic operations* have been performed with the electrosurgical cutting current with the advantage of sealing over capillaries and lymphatics. Seven or eight years ago, when Howard A. Kelly first took up electrosurgery, it was my privilege to be his assistant at most operations. At that time he used a cutting current for practically every form of pelvic operation, hysterectomies, panhysterectomies, myomectomies, salpingectomies and oophorectomies, this extensive application being made in an effort to determine the value of the cutting current as an operating instrument in addition to its prior claim in the treatment of malignancy. It is fair to say that this is a safe and efficient method for these operations, but its advantages are limited. The small vessels in the broad ligament and ovarian regions can be clamped and coagulated with safety, but the larger ones, particularly the uterine and ovarian, must be ligated as usual. It is a safe rule always to ligate any large vessel in the pelvis or abdomen when possible rather than rely upon coagulation alone. The cutting current in itself is particularly advantageous in dissecting densely adherent areas. How frequently tubes, ovaries, myomas, etc., found attached to loops of bowel or other organs in the pelvis offer tedious and bloody problems for scalpel surgery, with severe shock to the patient. In such, a carefully regulated cutting current readily severs the adherent organs with so little bleeding that at times there results a practically dry incision. Loops of bowel are thus quickly and easily dissected with less danger from the reformation of adhesions because of the protective coagulum remaining a few days before absorption.

Densely adherent *ovarian cysts,* benign or malignant and considered inoperable with the scalpel, are extricated by the current with great facility, in most cases the entire cyst wall being dissected away. Where this is impossible, the actively growing cyst wall is sliced off by the current, leaving the harmless outer portion attached to the intestine or abdominal wall to be absorbed later. Occasionally, with malignant cysts, where even this procedure is impossible on account of extensive erosions of the adherent viscera, the lingering portions are exploded out of existence by a strong coagulating current, leaving a perfectly sterile dry field.

Robert Fowler reports successful electrosurgical *vaginal hysterectomies* and a *cesarean section,* mentioning the only serious complication following electrosurgical abdominal hysterectomies of which I am aware, although I have never seen it. His patient died of embolus, attributed to some electrical injury to a large pelvic vessel. He also describes a new way of approaching a huge, otherwise inoperable

mind at all times, particularly when a malignant cervix treated and healed by irradiation begins to ulcerate in a few months or even in two or three years. Biopsy readily distinguishes between a delayed radium "burn" and recurrent malignancy and is a diagnostic requirement before subsequent radiation is carried out.

So important is this that I cite a case: A white woman, Mrs. N. B. M., age forty-eight, had an abdominal panhysterectomy in June, 1929, followed by a prophylactic radium treatment. The patient was in excellent health until December, 1929, when on routine reëxamination a small ulceration was noted in the vaginal vault. Another radium treatment was given without biopsy, and she continued well until three weeks before being referred to me in March, 1930. Within these three weeks a foul, watery vaginal discharge developed, associated with marked vesicle and rectal irritation, pain and bleeding. On examination the whole vagina, which was rather small, was seen covered with typical grayish-white radium slough. Cystoscopic examination revealed a large, reddened and irritated area on the trigone opposite the treatment site. Proctoscopy demonstrated a more marked reaction in the rectum at the level of the old cervix. A long period of severe pain and reaction followed, and subsequently a large rectovaginal fistula occurred which has only partially healed. The bladder is still a source of great distress, with repeated accumulation of urinary calculi over the sloughing ulcer, although there is no evidence of recurrence of the growth. It would appear that this stormy convalescence could have been avoided by biopsy of the recurrent ulcer, determining the need or lack of need of the last irradiation. Over-irradiation is easily possible in the thin-walled vagina, especially after removal of the cervix, which acts as a filter when present.

Deep x-ray or heavy radium-pack treatments used for transpelvic irradiation are associated with a mild skin erythema beginning about a week after application and lasting a variable period, blondes being more sensitive than brunettes. This erythema gradually fades in the course of two or three weeks, and the skin takes on a bronzed appearance not unlike a sun or ultraviolet tan which remains for many months without discomfort.

There are two biologic changes following intra-uterine irradiation: (1) endometrial and (2) ovarian. Cloudy swelling and erythema, infiltration of leukocytes and phagocytes, fibroblastic organization, obliterating endarteritis and scarring—all occur in the endometrium and underlying muscles of the uterus. The obliterating endarteritis accounts for the reduction in bleeding and partly for the amenorrhea. There may be some specific effect upon the uterine musculature, large fibroids readily disappearing and the uterus returning to normal.

The ovary presents a variety of structures, all of which are sensitive in proportionate degrees to irradiation with x-ray or radium. The ova and epithelial follicles are more sensitive than the stroma. The sensitivity of the follicles themselves depends upon their stage of develop-

SECTION III

IRRADIATION THERAPY

Physics

As a detailed discussion of the physics of irradiation therapy is given elsewhere (see Desjardins and Burnam, Vol. III), attention here is focused upon the application of these therapeutic agents in gynecology.

Biophysics

Reference should be made to these chapters (see Desjardins and Burnam, Vol. III) for study of the biophysical reactions of irradiation therapy, although it is important to rehearse some of the changes noted in treating gynecologic diseases.

As the gamma rays of radium or x-ray enter living tissues, chemical processes are started which do not appear immediately but are evidenced later by marked local changes in the diseased areas. The first noticeable alteration is an erythema resulting from dilatation of the blood vessels. In ulcerative growths, say of the cervix, this erythema may appear in two or three days and remain a varying length of time until the cervix is healed or until there is sufficient accumulation of fibrinous exudate on the surface to cover the underlying redness. Microscopically a cloudy swelling of the cells is seen within twenty-four to forty-eight hours, the cytoplasm being distended and pale, the nuclei swollen and pyknotic, and in three or four days the entire cell is undergoing rapid degeneration. The capillaries and blood vessels are enlarged and distended with blood, plasma has filtered out into the surrounding tissues, and leukocytes and phagocytes are abundant in the perivascular structures. As the injured cells degenerate, the phagocytes commence their work of clearing away the débris. In the second and third weeks, fibroblasts and new blood vessels grow in, organizing the tissue and producing a fibroblastic structure that becomes so very dense as to be characteristic of irradiation cicatrix. This same fibrosis involves the vessel walls, so that those which were once dilated and engorged with blood immediately following the treatment gradually return at first to normal size, their lumina then continuing to become slowly and steadily closed by an obliterating endarteritis. This process does not always cease with the scarring, but may progress, depending upon the amount of treatment, to the extent of obliteration of most of the vessels, with markedly reduced nourishment and subsequent breaking-down and ulceration at a period remote from the time of application. This is not common in gynecologic conditions unless heavy treatments are given, and then is most commonly seen in the thin-walled vagina. This possibility should be borne in

mind at all times, particularly when a malignant cervix treated and healed by irradiation begins to ulcerate in a few months or even in two or three years. Biopsy readily distinguishes between a delayed radium "burn" and recurrent malignancy and is a diagnostic requirement before subsequent radiation is carried out.

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The ovary presents a variety of structures, all of which are sensitive in proportionate degrees to irradiation with x-ray or radium. The ova and epithelial follicles are more sensitive than the stroma. The sensitivity of the follicles themselves depends upon their stage of develop-

ment, the mature ones showing most marked changes. The number and degree of follicles destroyed vary with the dose, and the steps in their reaction to the irradiation are comparable to spontaneous, physiologic atresia. With the death of the follicles, sterility naturally occurs and may or may not be permanent according to the severity of the treatment. The interstitial cells are not directly influenced by irradiation but gradually and slowly disappear, probably due to the destruction and eradication of the follicles, preventing the interstitial cells from being renewed.

Radiation Sickness

Radiation sickness is a term describing certain symptoms arising as a sequel to radium or x-ray treatments. In gynecology this most commonly follows deep-therapy treatments with x-ray or radium packs, to a lesser degree after intra-uterine and cervical irradiation, more marked when such treatments are given under general anesthesia, which causes part of the symptoms.

The symptoms vary in intensity, depending upon the amount and duration of treatment and sensitivity of the patient, passing off in a few hours or lasting a day or more. Usually there is only anorexia and nausea, in others nausea and vomiting which, in severe reactions, may continue for twenty-four or forty-eight hours and occasionally longer.

These symptoms are more pronounced when irradiating the abdomen, particularly the stomach and liver, although they have been known to occur following intensive irradiation of other parts of the body, the generally accepted view of the cause being that certain toxic products of cellular destruction are liberated into the blood stream and act as poisons. Irradiation of the intestines, containing a large amount of semidigested or residual organic matter, naturally gives more marked symptoms because of the larger quantity of toxic products liberated in the bowel and later absorbed into the blood stream.

Treatment of this uncomfortable complication is at best unsatisfactory, as no specific is available. The preparation of the patient before irradiation is an important aid in limiting the symptoms. The bowels are thoroughly cleared of fecal matter, a source of secondary radiations, with either a laxative the night before, or an enema the morning of, the treatment. Fasting for several hours is also of benefit in lessening the nausea. Elimination of foods for several hours afterward usually reduces the amount of vomiting, although most patients do not want food for some hours or perhaps a day if the symptoms are at all marked. A most important factor contributing to irradiation sickness is the overcrowding of treatment; long, heavy, deep-therapy treatments through the pelvis, whether with radium or x-ray, tend to cause more sickness than broken doses allowing the patient to react from one treatment before another is administered. Drugs giving the

most benefit are rather simple remedies: Alkalinization with bicarbonate of soda or other medicaments during the day prior to the treatment may be of benefit; citrous fruit juices and crushed ice sometimes relieve the nausea. Fifteen or twenty drops of compound tincture of cardamom and fifteen or twenty drops of compound tincture of hyoscyamus with twenty grains of bicarbonate of soda, given three times a day, often allay the vomiting. Fortunately, irradiation sickness gradually passes away and rarely causes any serious complications, although frequently distressing to the patient.

Artificial Menopause

Cessation of the menstrual cycle following irradiation of the pelvic organs is a common and often desired sequela, permanent or temporary, according to the strength and type of treatment. It is always permanent following irradiation of carcinoma of the cervix and body of the uterus. Irradiation for benign bleeding, particularly in young people (under thirty-five), can be so carefully regulated that the artificial amenorrhea can be made to vary from six months to two years. This is not uncommon even with large fibroids, for, as the tumors disappear and the uterus returns to normal, the ovaries again begin to function and the menstrual cycle returns. An interesting case has been reported by Curtis F. Burnam (personal communication) of a woman who married rather late in life, then was irradiated for fibroid with cessation of the menstrual periods for about a year. Following this, she became pregnant and gave birth to a perfectly normal child.

Transpelvic irradiation with high-powered x-ray or radium packs in proper doses causes artificial menopause. Mild irradiation (one-third to two-thirds sterilizing dose), particularly in women under twenty-five or thirty, will sometimes control an abnormal menstrual flow without complete cessation, the ovarian functions apparently being only partially influenced. If the full amount of transpelvic irradiation permitted by the skin (erythema dose) is given, the menstrual cycles are almost certain to be completely checked, particularly in women over forty, variations within certain limits proving the rule.

Irradiation Technic

Complete discussion of the technical problems of irradiation treatment may be found in Volume III (DesJardins and Burnam), but it is important to describe briefly the technic as applied to gynecologic disease as each is discussed.

External radium treatments by the pack method are administered in two ways. The early technic employed an open pack of felt, balsa wood or other light substance to maintain the exact distance between the radium and the skin. On the top of this pack was a small metal

box, usually 1 or 2 mm. of lead, in which the radium or radon tubes, as the case might be, were held. The use of platinum-filtered tubes necessitates another filter of aluminum foil to filter out the secondary platinum rays, and ametal rubber for the secondary aluminum rays, the rubber not being so important with large packs of considerable thickness of felt or wood through which the rays travel.

The newer method utilizes a large lead cylinder or bomb carrying the radium in such a manner that the rays reach the patient through an opening on one side or one end, the scattered rays being absorbed by the lead wall of the container. So far as I am able to ascertain, this

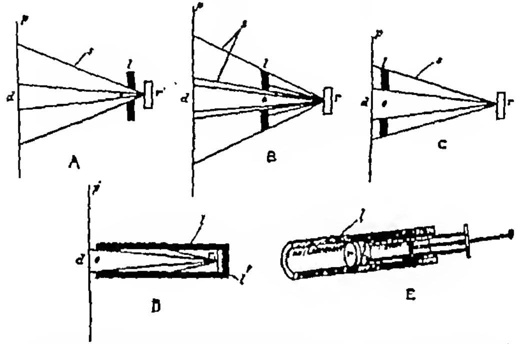

FIG. 14.—Diagram of the principle of plain lead filters as compared with Ward cylinder. Lettering in all diagrams is as follows: (r) box containing radium emanation; (l) lead filter with portal (o); (p) skin of patient; (s) rays. A, lead filter (l) next to radium. B, lead filter (l) midway between radium and patient. C, lead filter next skin. D illustrates rays absorbed by cylinder walls, only those destined to reach lesion being unobstructed; (l') represents one inch of lead in cover of radium carrier (r) affording protection of nurse's hand during insertion or removal from cylinder. E, longitudinal sectional view of cylinder containing radium carrier, the latter being equipped with handle facilitating manipulation. The length of the handle and carrier together corresponds to length of cylinder. A scale is so arranged on handle that as carrier is moved in cylinder the number of inches read at distal end indicates distance of filtration.

type of apparatus was first used by Stenstrom at the State Cancer Hospital in Buffalo. He arranged a mechanical device to rotate the charge of radium tubes of unequal strength within the cylinder in order to make the beam of rays that reached the patient as nearly uniform as possible. The author, independently of Stenstrom's work, designed a lead cylinder (Figs. 14 and 16-19) with a two-inch aperture and a lead wall of one-inch thickness. This apparatus was put into use

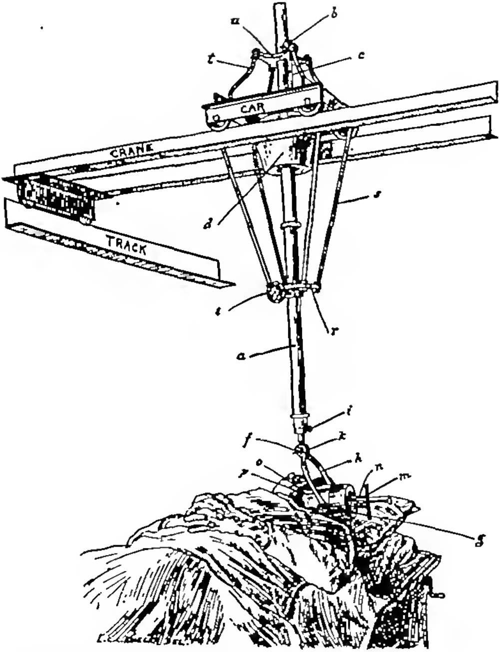

FIG. 15.—Suspension apparatus and cylinder "set up" as in treatment of a parotid tumor; (a) shaft; (b) pulley carrying cable (c) which suspends shaft and counter-balancing weight (d); (e) safety hand screw; (f, g and i) thumbscrews for adjusting cylinder; (k) cogs preventing ball (b) from slipping; (n) scale on handle (m) of radium carrier; (o) aluminum filter cap; (p) sheet rubber filter; (s and t) braces ending in brass plates (u and r) which prevent any swaying of shaft.

at the Howard A. Kelly Hospital in the early part of 1923. This cylinder weighs twenty-five pounds and is carried by a car running on a crane travelling on an overhead track (Fig. 15). Patients are placed on the Burnam treatment table (Fig. 20) with lead protection beneath, preventing irradiation of any patient or hospital workers in the room below. A few years ago the Memorial Hospital in New York City made a much larger radium bomb to carry permanently several grams of element. Such apparatus assures accurate application without injury to the surrounding parts and without unnecessary general body irradiation from the scattered rays which occur with the open package.

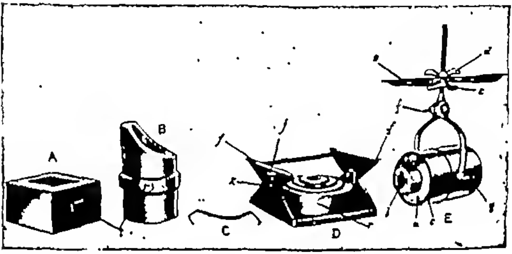

FIG. 16.—A, "square cylinder." The advantage here is that in treating adjacent areas square portals leave no portion of tumors unradiated: (t) holes for thumbscrews which hold cylinder in suspension apparatus. B, a cylinder with proximal end cut to fit curved surface of skull, used in treating an inoperable brain tumor from five angles without overlapping. C, aluminum filter cap curved to fit cylinder B. D, set of treatment rings shown in car to carry them running on track of portable suspension table shown in Fig. 19; (r) lead rings; (f) flanges to fit tracks; (j) thumbscrew which tightens against track and serves as brake on the car; (k) thumbscrew adjusting angle of car and rings with skin. E, 2-inch cylinder with adjusting apparatus as used with portable suspension table shown in Fig. 19. In figure a longer cylinder (b) with a 1-inch portal projects from 2-inch portal of larger and shorter cylinder, and is used in treating glands and smaller tumors; (a) wall of 2-inch cylinder made of 1 inch of lead; (c) ¼-inch brass reinforcing lead; (f and g) thumbscrews for adjusting cylinder to any angle with *the skin; (o) car for portable suspension table seen in Fig. 19; (d and e) wing nuts* for adjusting height of cylinder.

In gynecologic procedures such instruments are especially valuable, particularly in treating diseases of the vulva, where the thighs must be carefully protected against scattered radiation when the pack is placed between them. Cross firing upon a tumor is possible without overlapping on the skin, otherwise often a source of severe superficial burns. This cross firing through several portals around the pelvis multiplies the number of rays actually reaching the disease in direct proportion to the number of exposures.

Intratumoral application of radon or radium element is of great therapeutic value in gynecology. Tumors of the vulva, large massive cervical growths and broad-ligament extensions are oftentimes treated by the implantation of platinum-filtered radon seeds (see Burnam,

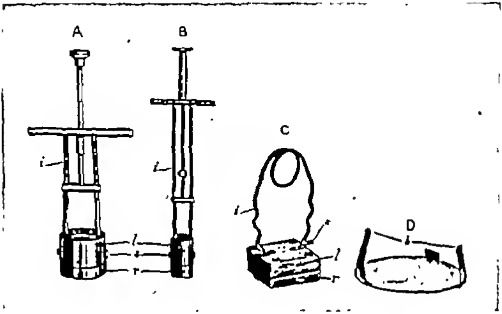

FIG. 17.—A, radium carrier for two-inch cylinder; B, for one inch cylinder; C, "square cylinder;" (l) one inch of lead in cover of carrier (in square carrier C it is ½ inch in thickness); (r) radium container of hard rubber reinforced with brass (no brass on bottom so that filtration is only through a thin layer of rubber); (s) brass studs so arranged that movements of crossbar of handle upward force them against the inner wall of cylinder, thus fixing carrier at desired point. In C, spring of handle serves to force studs against cylinder wall; (i) scale in inches indicating distance of radium from mouth of cylinder; D, aluminum filter cap for two-inch cylinder. This slips easily over proximal end of cylinder and is held in place by brass springs (b) at sides.

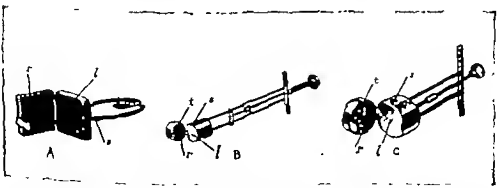

FIG. 18.—B and C, radium carriers for one-inch and two-inch cylinders respectively, open to show pockets (t) for radium tubes; (s, l and r) as in Figure 17; A, carrier for square cylinder, open to show plain brass box (r) without separate holes for each tube. This is used when radium tubes vary in size.

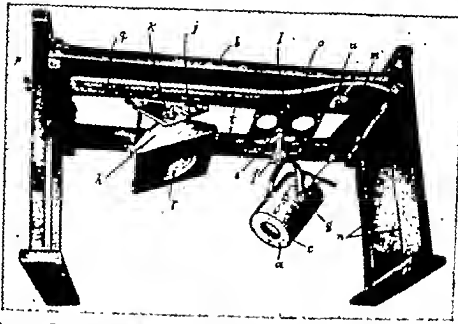

FIG. 19.—Portable suspension table; (n) two vertical slots in end of table through which pass bolts from adjustable top (b) allowing it to be fixed at any desired height by tightening thumbscrew (p); (t) track; (b and o) cars. One track is pivoted at (q), end (m) being movable so that by spreading the cars may be taken off or put on; (u) thumbscrew for tightening movable end of track; (l) brake for car; (o) thumbscrew removed. Other lettering as in D and E, Fig. 14.

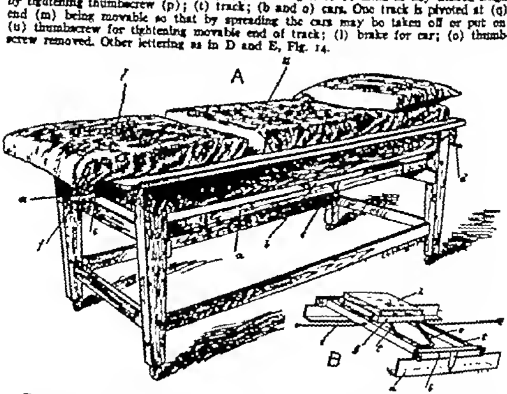

FIG. 20.—A, Burnam treatment table. (a) Track of two-inch angle iron; (b) end of crane with arrow indicating center; (c) handle for moving car; (d, e and f) crank, rope and pulley respectively, used for moving crane; (l and u) lower and upper mattresses respectively, separated to show construction. B, insert showing crane (b) and car (g) carrying one-inch lead block (h) 18-inch square; (t) tracks on crane for car (g); (c, e and a) as in A

Vol. III) or *radium element needles made out of an alloy of platinum and iridium.*

Flat vulval or vaginal growths are best treated by plaques fitted to the size and shape, with protection of the surrounding normal structures. During application to a malignancy on one labium, the other is protected with lead, or the cylinder just mentioned may be pulled

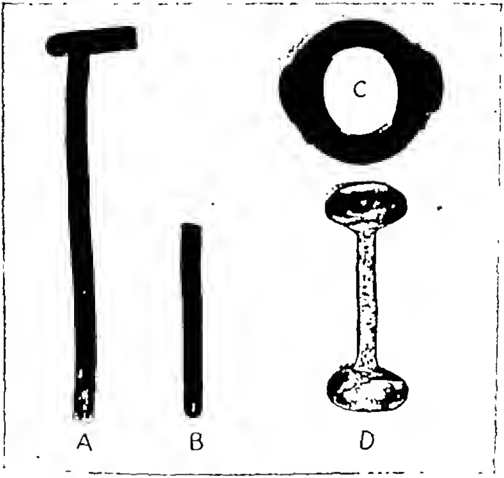

FIG. 11.—Ametal rubber cervical, uterine and vaginal applicators.

A. T-tube—radium charge placed in hollow cross tube to be laid directly against cervix—often inside of pessary "C."
B. Tube for insertion into uterine or cervical canals.
C. Pessary—made in various sizes to fit around the cervix. Radium beneath filters on each side, radiating broad ligaments; filters hold vaginal walls away.
D. Dumb-bell applicator for holding radium beneath bases of broad ligaments, when pessaries do not fit cervix.

down tightly against the involved one, and the radium placed as close as necessary to give the desired dose.

Vaginal treatments require a great deal of care on account of the proximity of the bladder and rectum and the thinness of the vaginal

wall, the entire thickness of which may be burned through without difficulty. The maximum dose against a vaginal-wall tumor should be about 1,000 mg. hr. per 2 sq. in. when the filter is 2 mm. of brass. One millimeter of platinum allows an increase of 30 per cent, as there are fewer soft gamma rays. The gauze plaque (Fig. 22) has varying numbers of little pockets in which the tubes are separately secured. Such plaques are also used in treating the cervix. Within the last year

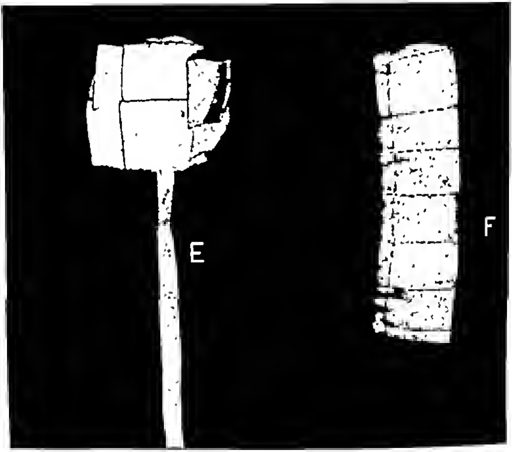

FIG. 22.—Cervical gauze plaques.

E. Round plaque with number of pockets varied to suit size of cervix.
F. Vicker's gauze applicator. After filling pockets with radium tubes, purse strings are pulled tightly, making a circular plaque.
(E and F developed at Howard A. Kelly Hospital.)

and a half I have been using radium element in tubes of platinum and iridium of 1 mm. wall thickness. This filters out all the beta and the softer gamma rays, but gives rise to harder secondary rays from the action of the gamma rays of radium on the platinum. To filter out these secondary beta rays the tube is surrounded by a thin film of aluminum foil and [illegible] and intracervical treatments is placed in an [illegible] of 2 mm. thickness. A metal rubber

pessaries and dumb-bell applicators (Fig. 21) hold a tube on each side of the cervix, radiating the broad-ligament region. I have not found this method as satisfactory as placing the individual tubes or plaques against the cervix, as each case presents individual problems and the pessaries are not pliable enough to meet all the demands.

Heymann, of the Radiumhemmet in Stockholm, has various sizes and shapes of silver boxes of 2 mm. of lead (Figs. 25-28). By carefully adjusting these to the cervix or vaginal wall, he is able because of their heavy filtration to give a much higher dosage than is

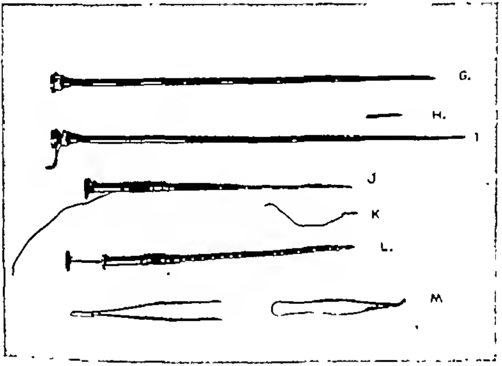

FIG. 23.—Intratumoral equipment.
G. Long, hollow implanter with obturator for inserting radium element needles.
H. Ten-mg. radium element needle.
I. Radium element needle projecting from end of implanter.
J. Radon seed implanter with seed projecting from end.
K. Platinum-covered radon seed.
L. Radon seed implanter with obturator.
M. Forceps for loading implanter.

common in this country. Cross firing may be added to this local application by placing tubes in the uterine cavity. Inasmuch as radium rays travel in all directions from the tubes, any placed in the vagina will tend to radiate into the broad-ligament region, the same being true of those placed up in the uterine cavity, so that radiation from both foci increases that delivered into the broad ligament, adding destruction to any migrating cells.

Intra-uterine irradiation of menstrual disturbances, fibroids and malignancy is the most direct method and therefore usually most effective. Brass-filtered radium tubes (2 to 3 mm. thickness) are placed in a container on the end of a uterine sound and dipped in wax to absorb the secondary rays from the brass. Platinum tubes require the special filters previously described, filtering out the secondary platinum rays with aluminum foil and 2-mm. ametal rubber cots securely tied at the end. Intra-uterine applicators require thorough

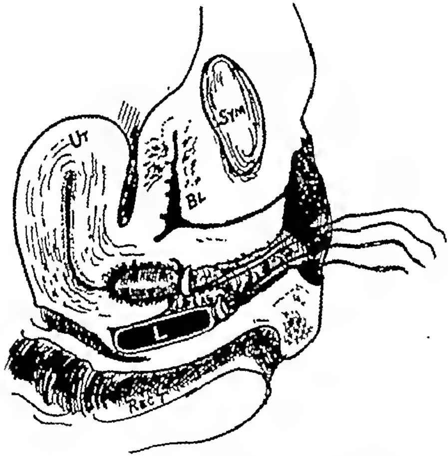

FIG. 14.—Method of protecting rectum after inserting radium tubes into cervix, lead filter protecting rectum; vagina packed with gauze.

sterilization either by chemicals or by boiling. The ordinary precautions taken for dilatation and currettage are necessary for intra-uterine irradiation of benign conditions, and rarely is there any complicating infection. However, in using the uterus as a focus from which to cross fire upon the broad ligaments in treating a carcinoma of the cervix, special care must be exercised in cleansing the cervix so as to avoid carrying the ever-present infection associated with the malignant cervix up into the uterine cavity. I have had one or two severe pelvic

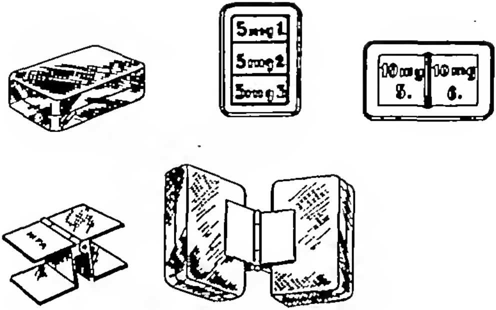

FIG. 25.—Boxes for vaginal application varying in size from 16 by 25 mm. to 36 by 56 mm. Height of all, 7.5 mm. The filtration is 2.3 mm. lead and 0.45 mm. silver.

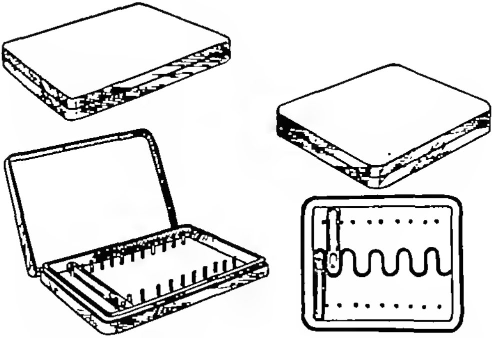

FIG. 26.—Flat boxes for vaginal application—filled with flat containers—filtration similar to Fig. 25. Some held together with clips to treat more than one surface at the same time.

inflammations follow such an application. In Europe this is the regular procedure and apparently without serious results.

Asherson reports three cases of cancer of the cervix treated by the transperitoneal route in addition to local application to the cervix. Four tubes, each containing 10 mg. of radium sulphate and screened with 0.3 mm. of platinum, were imbedded around the growth in the base of the broad ligament and in one case in the left ureterosacral fold. He feels that this adds materially to the amount of radiation poured into the cervix, but the technic has not been universally adopted and it is not without dangers.

Application of Irradiation

Vulva.—Treatment of vulval diseases calls for careful protection of the thighs, as already outlined, and a dose carefully calculated for each lesion, guarding against possible burning.

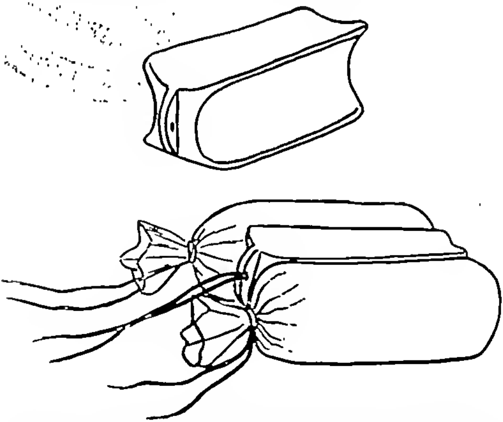

Fig. 27.—Celluloid sledges for holding cylinders or capsules in place within a craterous cervix, keeping the radium far out toward the sides nearer the broad ligaments. The narrow area of anterior and posterior wall of the crater from 4 mm. to 11 mm. in width, depending upon width of sledge, remains uncovered by radium, but receives practically as powerful a radiation from cross firing from the two sides. There is the added advantage of somewhat reducing what would otherwise be an added intensity of radiations at those spots (rectum and bladder) where, according to experience, injuries most frequently arise.

Pruritus vulvae, a distressing malady, is markedly relieved by the local application of radium close to, but not on, the skin. The dose usually varies from 300 to 400 mg. hr. at ½-inch distance over an area about two inches square. Should the disease extend posteriorly about the anus, an additional area is necessary, the same dose being given over each. One treatment usually stops the itching and improves the condition in the ordinary cases, but involvement of the deeper skin layers requires a repetition in four to six weeks, depending upon the result of the first application.

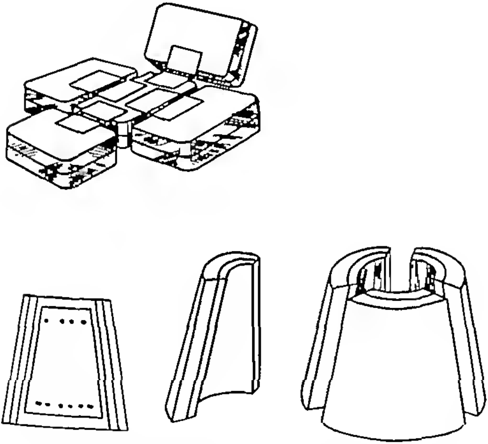

Fig. 18.—Small flat boxes held together with clips for application to cervix and vagina or both at once. Container shaped to suit a cauliflower growth.

Venereal warts are commonly multiple and extensive. The smaller ones are frequently eradicated with electrodesiccation; the extensive cases oftentimes demand electrosurgical excision. (See Section II.) Radium and x-ray, however, are exceedingly important adjuncts either in conjunction with electrosurgery or as the sole therapeutic agent. The treatment here is somewhat heavier than that necessary for pruritus vulvae, running up from 500 to 600 mg. hr. at ½ inch from

the skin, repeated in four or five weeks, if necessary. Occasionally a third or fourth application will be required completely to eradicate the disease. By this careful broken-dose method, reactions are avoided and the warts gradually melt away, leaving a healthy-looking, normal, soft skin.

Carcinoma and *sarcoma* of the vulva are treated with irradiation therapy, frequently in combination with electrosurgery, particularly in the resistant and extensive cases. The abundant loose skin about the vulva permits easy electrosurgical excision following irradiation, assuring quicker and less painful healing and a softer scar. Here, the irradiation dose must be heavier than that for the benign condition in order to affect the more resistant malignant cells. Usually 1,000 to 1,500 mg. hr. are given at ¼-inch distance over two square inches of area, deeper involvement requiring implantation of radium element needles or radon seeds. Heavy irradiation reaction is not so much feared when the tumor is to be taken out electrosurgically after irradiation, as the removal obliterates the slow, painful healing. A combination of therapy is, as a rule, more efficacious, as an increased radium dose is possible, and two therapeutic agents are used in place of one. The lymph-gland-bearing areas are given a prophylactic erythema dose with x-ray or radium pack, and any large demonstrable metastasis implanted with radon seeds or radium element needles. Post-irradiation care consists of cleansing the part regularly and the application of a mild ointment for protection and keeping the parts soft.

Vagina.—*Benign polyps* of the vagina are uncommon and readily removed with electrosurgery, as already outlined.

Carcinoma of the vagina offers an insurmountable task from any surgical standpoint; however, as a rule, the condition is sensitive to irradiation, which gives five-year clinical results and splendid palliation in the more extensive cases. Intravaginal irradiation is coupled with accurate transpelvic treatment with radium packs or x-ray covering all of the gland-bearing areas. During the local application, the highly sensitive rectum and less sensitive bladder are carefully protected by packing off with gauze or covering the applicator with filters of ⅛ or ¼ inch of lead wrapped in aluminum foil to absorb the secondary lead beta rays. These organs are easily damaged, with liability of fistulas making the patient exceptionally uncomfortable, complications which are practically always avoided by carefully applying the radium, accurately calculating the dose and then packing the vagina, keeping the treatment away from all the normal tissue. When the disease is located near the outlet, it is best first to pack the gauze above, then apply the radium and fill the remaining cavity with gauze to hold the radium in place. Sometimes, particularly in the small vagina commonly found in the elderly patient as a result of senile changes, small lead filters are of special protective value. Implantation in vaginal cancer is dangerous, as the thin vaginal wall allows easy

injury to surrounding organs, and it is rarely necessary on account of the relative superficialness of the growth itself yielding readily to direct applications. As the radium is laid directly against the growth, the determination of the dose and filtration is important. I prefer heavy filtration of 1 or 2 mm. of platinum or lead and aluminum foil and 2 mm. of rubber, filtering out all the soft rays, allowing only the hardest penetrating gamma rays to reach the growth. One thousand milligram hours distributed over two square inches of growth have in my experience given the best results. Where the disease has extended on two or more sides in the vaginal cavity, the pack must be moved from time to time, to cover the entire involvement. I usually use a small amount, say 75 to 100 mg. for from 10 to 15 hr., varying the dose as necessary.

Cervix.—*Benign* cervical diseases offer much for irradiation therapy. Various reports have been made of the advantage of radium treatments in *endocervicitis*, an inflammatory condition which, as a rule, is best handled by cauterization or electrocoagulation. (See Section II.) The same may be said of benign polyps, easily removed with the cautery or high-frequency current, in which, should any malignancy be found, the base is thoroughly destroyed and adequate irradiation given as a prophylactic measure.

Cervical malignancy is one of the most fertile gynecologic fields for irradiation therapy because of the ease of approach and concentration of dose, and sensitivity of the cancer, usually predicted by the microscopic picture. Biopsy is a routine confirming the diagnosis and aiding the prognosis. Martzloff, Broders and others have shown that basal-cell tumors (which are less differentiated) are the most sensitive to irradiation, while squamous-cell, or the more highly differentiated type, are less sensitive in direct proportion to the amount of keratinization observed microscopically, for, the nearer the cells are to the adult squamous type, the less response is there to the rays. Adenocarcinoma is still more resistant. The microscopic picture, then, is of great help in prognosticating any individual case, but not always the sole factor, as there is a great difference in the individual variation within any one particular type.

Statistics show that in the early so-called operable cancers, as high a percentage of five-year results is obtained by irradiation as with any operative procedure. This is without a primary mortality, so that in reality the odds are in favor of irradiation therapy. In spite of the efficient cancer propaganda for the last ten or fifteen years, we still see a large number of cases, 70 per cent in my series, coming in the borderline of inoperable cases, either because of the late development of symptoms, the patient's own fear of cancer and therefore neglect of investigation, or because of the physician's ignorance as to the proper diagnosis. Surgery offers nothing in this group. The author, reporting 231 cases occurring during 1921 and 1922 at the Howard A.

the skin, repeated in four or five weeks, if necessary. Occasionally a third or fourth application will be required completely to eradicate the disease. By this careful broken-dose method, reactions are avoided and the warts gradually melt away, leaving a healthy-looking, normal, soft skin.

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Clinic and others, maintaining that small amounts of radium given over a period of a day or two and repeated once a week for three weeks are more efficacious. I have found that the latter method gives the best result and have adopted the plan of breaking up the calculated total dose into three smaller ones given one or two weeks apart. In support of this theory, its advocates maintain that inasmuch as cells are vulnerable during mitosis, more are affected by exposure to a small amount of radium over a long period, and repetition of the dose on two or three successive occasions destroys a still larger number.

Following the first treatment, there is a period of erythema, after which the cervix gradually shrinks and whitens, being covered with a grayish "radium slough." Bleeding soon stops, and the discharge lessens in proportion to the amount of the cervical contraction and healing. In from six to eight weeks the cervix is entirely healed and replaced by a firm cicatrix. This is quite uniformly the case, even when broad ligament and perimetrial invasion has been noted at the first examination.

After four to six weeks from the first treatment, it is safe to cross fire through the pelvis with radium plaques or x-ray; the full erythema dose is given through each of several portals, two being most commonly chosen, one over each broad ligament, with careful protection from overlapping on the skin. A third portal may be chosen through the sacrum, if indicated by much extension into the posterior pelvis.

Recurrences are treated as they develop. The reappearance of local disease is combated by applications similar to the first, the dose usually being one-half to two-thirds that originally given. Lateral extension in the broad ligaments in the form of a sclerotic mass, or growth posteriorly as a fan-shaped diaphragm on each side and encircling the rectum, is best treated by cross firing through the pelvis, as previously outlined. Larger massive recurrences are implanted, after thoroughly sterilizing the vagina, with radon seeds when available, as they can be left in place, although removable radium element needles are just as efficacious. On the basis of one millicurie of radon permanently implanted giving 133 millicurie hours of treatment, the dose is varied from 500 to 1,200 mg. hr., depending upon the size of the mass. With radium element needles, the dose is the same and calculated on a time milligram basis as in any other local application.

The complications which may arise following irradiation of carcinoma of the cervix depend upon the extent of the disease at first examination and the skill with which the application is made and dose calculated. Bladder or rectal fistulas are rare when careful precautions are observed and provided the growth did not involve the anterior or posterior vaginal walls to any marked degree before treatment was begun.

Kelly Hospital, showed that even in this surgically helpless group, 28 per cent of the local lesions were healed and 44 markedly improved, with a clinical four-year arrest of 15 per cent. One year later, which brought these statistics up to the five-year period, there were 10 per cent clinically well and without demonstrable disease.

Early cases, presenting as small ulcers on the cervix or limited involvement in the canal, are treated without preliminary cauterization. In the more advanced, removal of a portion of the cervix with the cautery or by electrosurgery allows the application at the outlying portions of the growth where activity is greatest and the treatment is concentrated. This combination is of special value in treating massive cauliflower growths which fill the vagina. The cervix is amputated with a strong cutting current and the base sealed with a strong coagulating current. Where this amputation is impossible or difficult, the growth can be removed with an electrosurgical loop back to firm tissue.

The application of the radium is made in one of several ways, depending upon the case at hand. The canal is filled with an ametal rubber cot containing platinum-filtered (1 to 3 mm.) radium surrounded by aluminum foil. A plaque similarly filtered is then placed over the cervix and held in position with suitable vaginal packing. Ametal rubber pessaries or dumb-bell applicators, with extra thick rubber filters around the tubes to keep them away from the vagina, guarding against burning, may be used to hold rubber tubes out under the broad ligament. I have found it rather difficult to apply these pessaries and dumb-bell applicators, as they are more or less fixed in size and shape and not adjustable to many cervices. *Extension* beyond the cervix into the broad ligaments requires implantation of radon seeds, or radium element needles are placed in the cervical tissue opposite the broad ligament or in the massive extensions.

Intra-uterine application in cervical cancer is advocated by many as an additional means of cross firing upon the broad ligaments. This is not without danger of infection being carried up into the uterus and an associated pelvic peritonitis. Cancers of the cervix always have a large amount of associated infection, usually streptococcus. In the few cases in which I have added intra-uterine irradiation, there has been a high percentage of infection in spite of preliminary cleansing of the cervix. There is less likelihood of carrying infection into the body if the cervix is cauterized, but no method of chemical sterilization will eradicate all bacteria lingering deep in the tissues.

With radium filtered with 1 mm. of platinum, the average cervical dose is 3,000 mg. hr., by the combined application of needles, tubes and plaques. With heavier filtration, say 3 mm. of platinum, the dose is increased to 4,000 or 5,000 mg. hr. Heymann, using the equivalent of 3 mm. of lead, gives 6,000 mg. hr. in broken doses, with impunity. There are two schools of dosage—one holding that a heavy, short application deals a death-blow to the growth better than repeated treatment, the other, supported by Bowing and Fricke of the Mayo

In two other patients in this group there were miscarriages. Neill concludes that pregnancy is possible after irradiation in selected cases.

For patients from twenty-five to forty years of age, the intra-uterine dose is increased to 1,000 to 1,500 mg. hr., producing amenorrhea for from one to two years with return of the menstrual periods in the younger group. Rarely is a patient resistant to one or two intra-uterine treatments and then requires hysterectomy. *Hyperplasia at the menopause* requires 1,500 to 2,000 mg. hr. with brass-filtered radium and 1,800 to 2,200 mg. hr. with platinum-filtered radium to bring about a complete cessation of menstruation. Artificial menopause is accomplished without serious complication other than that which would have occurred had the menstrual cycle ceased in the normal, physiologic way.

Fibroid tumors of the uterus are especially susceptible to irradiation given internally or transpelvically, although intra-uterine application is quicker and more certain. The size of the tumor, per se, is not a contraindication to irradiation therapy, but pedunculated subserous growths, submucous tumors, calcified fibromas, an incarcerated uterus, an obscure diagnosis or acute pelvic inflammatory diseases require surgical intervention. Uterine fibroids so densely bound down by old inflammatory adhesions that their removal is an unwarranted risk respond to irradiation and, shrinking to normal, or nearly so, all bleeding ceases. Reduction of a densely adherent uterus is sometimes associated with abdominal discomfort caused by pulling on the adhesions, a symptom of minor importance considering the patient's general well-being. The degeneration of fibroma into sarcoma by irradiation has not been established, as such cases reported in the literature were probably malignant from the beginning. The fibroid dose of intra-uterine radium is about the same or perhaps a little larger than that required for permanent amenorrhea, as previously described. X-radiation and radium pack for fibroids act through the effect of the rays upon the ovary more than directly upon the tumor itself. Intra-uterine irradiation, however, has a double action; first, an obliterating endarteritis of the endometrial vessels and, second, an inhibition of ovarian activity. Some authorities believe that excessive bleeding with marked anemia is a contraindication to irradiation, as it is imperative to stop the bleeding immediately. Hysterectomy is also not without its dangers in such patients. Dilatation and curettage under gas anesthesia, or in the nulliparous without any anesthetic, are associated with much less risk and bring about almost uniformly a complete cessation of the hemorrhage until the radium has had its effect. Submucous fibroids or fibroid polyps require surgical removal, as irradiation against these gives rise to sloughs of varying degrees of severity with infection and foul discharge, without eradicating the tumor.

Malignant Diseases.—Adenocarcinoma of the uterus usually occurs at or after the menopause. Curettage reveals the diagnosis, but

Uterus.—Irradiation of uterine disease has been a blessing to many thousands of patients by sparing them the dangers and mutilations of operations for the removal of one or more pelvic organs.

Benign Diseases.—Many thousands of women have had their uteri saved by irradiation control of irregularities in menstrual flow or eradication of fibroid tumors. What a pity to deprive unnecessarily a young woman of her pelvic organs and hopes of normal sexual activity, by removing the uterus for a menstrual irregularity or small fibroid tumor. Many cases are on record of perfectly normal menstrual and sexual functions and the occasional birth of a normal child after uterine irradiation.

Hyperplasia of the endometrium is most frequently encountered at the beginning or termination of the menstrual cycle. In young women under twenty-five, the intra-uterine dose is from 400 to 1,000 mg. hr., with brass-filtered radium, and about one-third more than this when 1 mm. of platinum, aluminum foil and 2 mm. of ametal rubber are used. In girls at the beginning of the menstrual period up to the later teens, one-half to two-thirds of an erythema dose with x-ray or radium plaques over the ovaries gives the same result without the necessity of instrumentation. Following such treatment, there may not be a complete cessation of the menstrual cycle, but a gradual reduction to normal flow. If amenorrhea occurs, it usually lasts six months to a year, gradually returning to normal.

W. Neill reports 30 cases of adolescent bleeding treated with radium at the Howard A. Kelly Hospital. In six of these the hemoglobin varied between 30 and 50 per cent. The youngest patient was 13 years old, and the oldest 25. He divided the cases into three groups: In Group I there were sixteen patients in whom the periods became normal immediately or within a few months after treatment and remained so. In Group II, five cases, there was temporary amenorrhea with a later return to normal menstruation. In Group III, permanent amenorrhea was established in six cases. All of these were treated by the intra-uterine method, with a dose varying from 184 millicurie hours to 1,300 millicurie hours, the maximum dosage being used in a person 24 years of age, who had had such extensive hemorrhages in spite of previous curettements that the hemoglobin was 30 per cent. Hysterectomy had been advised, but refused by both patient and parents. After irradiation, immediate cessation of hemorrhage occurred, but irregular bleeding continued for eight months, when normal periods became established and the patient's health steadily improved.

In Group I of Neill's cases, one patient married one and one-half years after treatment (12 years ago) and gave birth to a normal child one year after marriage (2½ years after treatment), and a year and a half later (4 years after treatment) there was a stillborn child at full term. Five years later, she was delivered of a second healthy child—both children being alive and normally developed at the time of this writing.

SECTION IV

HYDROTHERAPY—DOUCHES

Hydrotherapy in gynecology is limited to perineal irrigations and douches, and occasionally sitz baths, irrigations and douches being most frequently employed as a cleansing agent following perineal operations, although ulcerating diseases of the vulva require irrigations for cleanliness and comfort. Irrigation solutions are usually similar to those for douching the vagina. Sitz baths relieve pain and tenesmus, and cleanse the external genitalia.

The real value of a douche is threefold—first, and most important, the mechanical irrigation; second, heat applied more closely to the seat of disease; and third, the chemical effect, of least value, as solutions strong enough for definite chemical action on bacteria often are irritating and usually do not remain in the vagina long enough for real antiseptic effect; neither do they reach the cervical canal, the seat of most leukorrheas. Saline and alkaline douches are soothing to the irritated vagina or vulva.

TECHNIC

Douches are best given by a nurse or an attendant, although ambulatory patients using the treatment at home, once or twice a day, have to irrigate themselves. A long, curved, hard rubber nozzle, most commonly satisfactory, is attached to a soft rubber bag by a long rubber tube. A special, *two-way douche nozzle*, with a *large* flange near the distal end, to keep the vulva apart, is preferable, thereby protecting the external parts from irritation from hot solutions, and at the same time making distention of the vagina possible, the solution escaping only through the outflow tube. The patient should lie on her back, preferably with the hips slightly elevated, assuring that the solution gets as high as possible (except in acute cases, when Fowler's position is essential to reduce extension up the cervix and uterus and out into the tubes). Advise against sitting on a commode while taking a douche, as the solution does not remain in the vagina long enough nor under sufficient pressure to distend all the folds of the vaginal wall.

Acute and chronic endocervicitis are the most common diseases requiring douches, although the heat of the douche is of great value in acute and chronic salpingitis.

does not always tell of the exact location and the extent of the involvement. For this reason, intra-uterine irradiation is liable of inaccurate application, and for many years panhysterectomy was considered the method of choice. Recently, Burnam and others have reported excellent results from intra-uterine irradiation, which compared favorably with those of panhysterectomy without primary operative mortality. The intra-uterine irradiation technic is as formerly described with two or three times the dose—as high as 3,000 or 3,500 mg. hr. being given with brass-filtered radium and 3,500 to 4,000 mg. hr. with platinum-filtered radium. In extensive cases this might have to be repeated as occasion demands, the repetition of treatment in any case depending entirely upon the progress. Marked palliation is obtained even in advanced disease involving the broad ligaments, particularly when the treatment includes transpelvic irradiation.

Ovaries.—As already mentioned, the ovaries are always affected when treating diseases of the uterus or the cervix.

Benign lesions of the ovaries, then, which are treated with irradiation, are only those dependent upon functional activity.

Carcinoma yields surprisingly well, but I believe an exploratory operation should always be done in the hope of removing the growth, or as much of it as possible, and allowing accurate localization of the remaining trouble for more effective postoperative irradiation. Irradiation of ovarian tumors without preliminary operation, except in rare instances where the tumor is massive and diagnosis is quite certain, is more or less working in the dark. I recall a patient of Howard A. Kelly's who had been operated on in a distant city and the diagnosis of inoperable, adherent, bilateral carcinoma of the ovary made without biopsy. Operation (at which I assisted) was performed in an effort to determine more accurately the exact nature of the growth and to remove as much as possible before irradiation. Two large chocolate cysts were found and completely removed, the patient making a splendid recovery. Electrosurgery was necessary to cut the tumors away from the densely adherent intestines.

The dose of radium or x-ray should be carefully calculated and delivered through as many portals as possible, cross firing upon the seat of the disease. An erythema dose is given through each portal, with careful protection of the skin to prevent overlapping.

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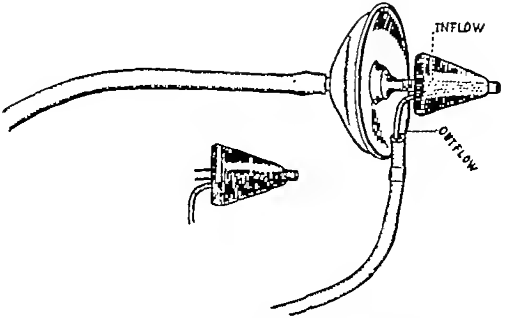

FIG. 29.—Urethral open applicator. (Courtesy of American Medicine.)

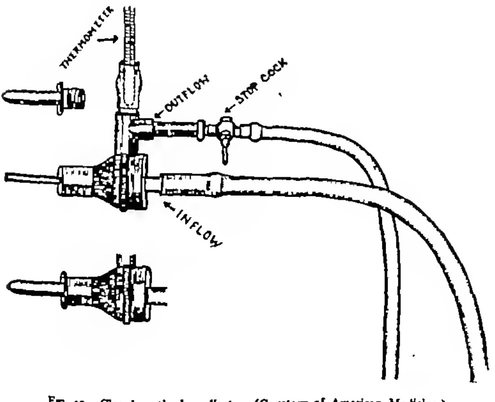

FIG. 30.—Closed urethral applicator. (Courtesy of American Medicine.)

Acute Gonorrhea

The local treatment of acute gonorrhea is only part of the therapeutic measures necessary to cure the local disease, prevent salpingitis and protect the other members of the household. The accepted general medical measures must always go hand in hand with douches and external irrigations.

In the acute stages, patients are usually in bed, where frequent and constant treatments are more readily given. The perineum and vulva are cleansed three or four times a day by copious irrigations, with a mild antiseptic solution, such as 2 per cent boric acid, bichloride of mercury (1:8000) or potassium permanganate (1:4000). Vaginal douches of similar solutions, at a temperature of 116° F. (46.67° C.), are given at low pressure, with the body elevated, preventing forcing the acute infection up into the cervix, uterus and out into the tubes. It is better here to use a soft rubber nozzle inserted a little way into the vagina, avoiding any abrasion. The heat inhibits the growth of the gonococci (Cherry); and large amounts of fluid, for instance, the long-employed gallon douches, greatly prolong the application to the cervix. After the acute stages have subsided, douches are supplemented by topical applications and other treatments, which are beyond the scope of this chapter.

Hyams [1] has described a unique instrument for, and method of applying, prolonged irrigation to the urethra and to the cervix and vagina, with hot solution at an exact temperature under accurate control. The accompanying diagrams are sufficiently illustrative without further description.

Acute Urethritis

The patient is requested not to void for at least an hour before treatment, which is applied in the lithotomy position. One ounce of 1 per cent silver nitrate solution is injected into the vagina, bathing its walls, as well as the cervix, and held by a pledget of cotton in the outlet. The urethral open applicator (Fig. 29) is connected to a tank containing sterile water at a temperature between 114 and 118° F. (45.56 and 47.78° C.), and the external parts cleansed by irrigation, after which the applicator is inserted into the urethra for about one-quarter of an inch and held firmly against the meatus to prevent leakage. Water is allowed to circulate at a temperature varying from 106 to 114° F. (41.11 to 45.56° C.), according to the tolerance of the patient, under a little pressure, distending the urethra so that its entire surface is accessible and flushed. Applications usually last twenty-five minutes; then a cotton applicator, saturated with 1 per cent silver nitrate solution, is inserted into the urethra and left for ten minutes. The pledget previously placed in the vaginal opening is removed, the urethra and vulva dried and dusted with a powder con-

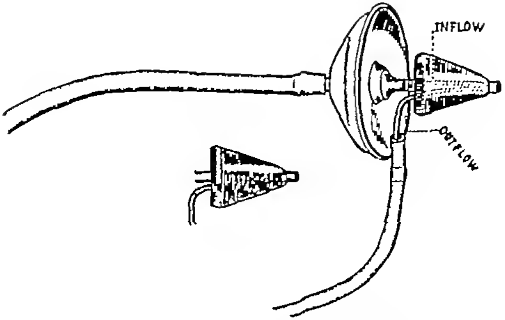

FIG. 29.—Urethral open applicator. (Courtesy of American Medicine.)

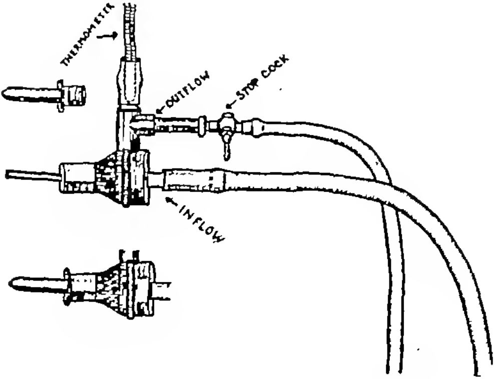

FIG. 30.—Closed urethral applicator. (Courtesy of American Medicine.)

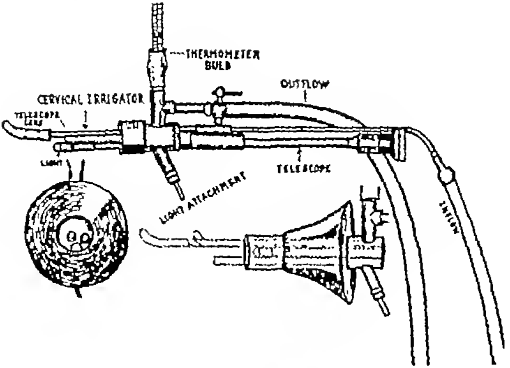

FIG. 31.—Cervical instrument.

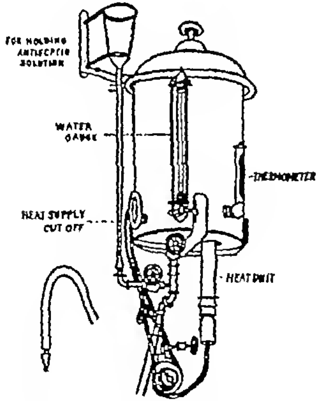

FIG. 32.—Tank for supplying sterile water at constant temperature.

sisting of one part xeroform and three parts boric acid. A closed applicator is used for repeated treatments (Fig. 30), after the acute symptoms have subsided; and the duration of the treatment, temperature and local medication are the same as in the open method. Daily sitz baths are essential, the patient being instructed to sit in the bath-tub and allow the hot water to run slowly and steadily for fifteen minutes by the clock. Detailed instructions are also given regarding general hygienic measures, regulation of diet, fluid intake and care of the bowels.

Acute Endocervicitis

Figure 31 shows Hyams' instrument for continued irrigations of the cervix and vagina. The preliminary technic is similar to that described in the treatment of acute gonorrheal urethritis. After snugly fitting the cervical instrument into the vaginal orifice, a thermometer is inserted, light attached, the rubber tube from the hot water supply connected to the instrument, and the irrigation started. The vagina immediately distends, and by looking through the attached telescope the water is seen loaded with pus and débris, resembling a "violent snowstorm," temporarily obscuring clear vision but soon clearing as the irrigation is continued. By manipulation of the cervical applicator, its tip is inserted just within the external os, the entire instrument then being held in place by a special holder, the water circulating at a temperature of 115 to 118° F. (46.11 to 47.78° C.). The patient experiences no discomfort so long as the circulating fluid remains confined within the vagina, but care must be exercised that none leaks around to irritate the skin. After twenty-five minutes of such irrigation the instrument is removed, and an ounce of 1 per cent silver nitrate solution is injected into the vagina to remain for ten minutes, bathing the cervix as well as the vaginal walls. The skin of the vulva is then dried and dusted with the same dusting powder. The patient carries out similar home treatment as when being treated for the acute urethritis.

Chronic Endocervicitis

Douches and tampons are the time-worn treatments for chronic endocervicitis. When the infection has penetrated deeply into the racemose cervical glands, chemical solutions on tampons and the mechanical irrigation rarely serve to clean up the outlying posts of the trouble. Hot douches are of value in stimulating circulation and cleansing the vagina of the accumulated mucoid leukorrhea but otherwise are of limited value. Chronic endocervicitis, as indicated under Electrosurgery, needs more drastic treatment. During convalescence from such surgical measures, douches are cleansing and comforting.

Malignant Disease of Cervix, Vagina and Vulva

As a matter of completeness, I reiterate what has been said elsewhere relative to the great comfort which douches are to the gynecologic patient suffering from malignant disease. Following irradiations of the cervix and vagina, there is always considerable vaginal drainage. Carcinomas of the vulva are associated with much weeping of serum and sloughing growth, always discomforting and annoying. An alkaline douche once or twice daily is most commonly used, as it neutralizes the acid, irritating secretions.

Douche Prescriptions

THE P. M. C. DOUCHE

℞ Acidi borici .... ℥ iv
Pulv. alum. .... ℥ i
Pulv. phenol. .... ʒ ii
Ol. menth. pip. .... ʒ i ss

Sig.: Mix well. A teasponful in a quart of warm water as a vaginal douche.

THE A. B. C. DOUCHE

℞ Pulv. alum. exsic. .... ℥ i
Phenol. .... ʒ i
Acidi borici .... ℥ vi
Ol. gaulth. .... ʒ i
Ol. menth. pip. .... ♏ xxx

Sig.: A teaspoonful in a quart of warm water as a vaginal douche.

℞ Acidi carbolici .... ʒ ss
Sod. biboratis .... ℥ ii
Acidi borici .... ℥ iii

Sig.: One dram in two quarts of hot water as a vulval douche, t. i. d.

℞ Ol. menth. pip. .... ʒ ss
Acidi carbolici .... ʒ i
Zinci sulphatis .... ℥ i
Acidi borici .... ℥ iv

Sig.: Two drams in one gallon of hot water as a vaginal douche, b. i. d.

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CHAPTER TWENTY-THREE

THE USE OF PHYSICAL THERAPY IN OPHTHALMOLOGY

SANFORD R. GIFFORD, M.D.

INTRODUCTION

While always depending to some extent on such physical therapeutic agents as heat and cold, ophthalmologists in general have been rather slow to make use of the modern agents of physical therapy, such as ultraviolet light, diathermy, x-ray and radium. This conservatism has probably depended largely on a very proper fear of possible damage to the delicate structures of the eye, cornea, lens and retina by these agents. Such possibilities of danger undoubtedly exist, and it is only through the experiences of a relatively few observers in recent years that we are now able to say just what these dangers are and to arrange proper dosage and filtration so that they may be avoided. As a result of the same observations, we are now able to say something as to the various conditions which are definitely benefited by these agents. This should mean only conditions in which phototherapy or radium, for example, offer advantages not enjoyed by the agents previously used, as needless expense and loss of time by both physician and patient should not be incurred by using more complicated methods and instruments for the treatment of conditions which are satisfactorily relieved by simpler means.

This chapter will attempt to consider, therefore, only the conditions in which physical therapy has very definite indications, and will give the technic and dosage which have been found safe and effective by observers with enough clinical experience to back up their statements.

THERMAL THERAPY

The use of heat and cold in ocular conditions should be governed by the same general rules as those for heat and cold elsewhere in the body. In the first stages of an acute inflammation, such as gonorrheal ophthalmia, acute conjunctivitis of other types or acute orbital cellulitis, cold applications often reduce the amount of swelling or prevent further swelling, and often relieve pain. They are best applied in the form of shaved ice in a thin rubber container such as a rubber glove with the fingers tied off. This is wrapped in one layer of thin

gauze and placed over the closed lids. Cotton pads wrung out of ice water are also effective. Cold in one of these forms is often used for alternate hours during the period when swelling may be expected. Such treatment is of special value after certain operations such as those on the extra-ocular muscles which are frequently followed by conjunctival swelling. In any case of iritis with much pain, cold packs for not over 15 minutes to one-half hour at a time may be tried and may be of great value in relieving pain. When an ecchymosis of the lids (black eye) or a subconjunctival hemorrhage first occurs, cold applications may cause contraction of the vessels and prevent further oozing. After 24 hours they are probably of no further value, and should be replaced by hot packs which seem to hasten the process of absorption.

The same is true in most inflammatory conditions in which, after the initial swelling has been minimized by cold packs for 48 hours, the use of heat is generally of more value.

Moist Heat.—In most cases moist heat can be efficiently applied, and requires no special equipment. A pad of cotton is placed on the eye, as the patient lies in bed with the eyes closed. First warm water, and then hotter water, is dropped on the cotton with an ear syringe or a dropper till the highest temperature which is tolerated without pain is reached. This temperature is kept up for 20 minutes and such applications are given three or four times a day. It is important to give proper instructions either to nurses or to members of a patient's family, when the effect of hot packs is desired. Patients should understand that with the lids closed, there is no danger in using ordinary water, and it is usually best, since if any solution, such as that of boric acid, is used, there will seldom be enough solution, or hot enough solution, to give a proper pack.

Dry Heat.—Where dry heat is desired, as after intra-ocular operations, the various infra-red lamps are clean, safe and effective. They should be placed at such a distance from the eye that the heat is not actually painful, and treatments should last 20 to 30 minutes. The heat of an ordinary reading lamp may be used for this purpose. Park Lewis has described a convenient small infra-red lamp made to fit snugly over one eye, which can be used by the patient himself. The *Kopflichtbad* used in many German clinics is a box which fits over the head and contains four to six electric light bulbs, which can be turned on to give varying amounts of heat to the head. The congestion of the head so produced is claimed to be more beneficial than packs to the eye alone.

Other methods of using heat, such as diathermy and the thermophore, will be described later.

Phototherapy

In using light on the eye or adjacent structures, there are several factors which make the effects different from those of light applied elsewhere in the body. Most important of these is the transparency of the ocular media, which allows access of certain kinds of light to the deeper structures, and which may be impaired by too great a dosage of active rays.

Absorption.—The normal cornea absorbs 50 per cent of the longer infra-red rays, between 18,000 and 16,000 A°, the other half being absorbed by the lens. Between 16,000 and 13,500 A°, the cornea absorbs almost all the light, while from 13,500 down to the beginning of the visible red rays at 7,700, an increasing amount is transmitted, reaching 100 per cent for the rays of the visible spectrum, 7,700 to 4,000. In the ultraviolet region it absorbs practically all rays below 2,950. The aqueous and vitreous humors transmit all rays which pass the cornea. The lens, besides absorbing most of the longer infra-red rays which pass the cornea, absorbs 25 per cent of rays between 13,500 and 11,000 A°, all the ultraviolet rays between 2,950 and 3,200 and part of those between 3,200 and 4,000. These ranges of absorption are important since it is only the absorbed light which is effective, or in larger doses, harmful.

Sensitiveness.—It may be expected that the cornea will be especially sensitive to ultraviolet light. It is sensitive not only because of its absorption, but because of its rich supply of nerve endings, and this sensitiveness is the second factor which must be considered as peculiar to the eye. When the cornea is exposed to a source of ultraviolet light of sufficient strength, an abiotic reaction begins after six to eight hours, with swelling and irregularity of the corneal epithelium, and the formation of vesicles. If the exposure is longer, the epithelium is completely desquamated, the corneal corpuscles show fragmentation of their nuclei, and eosinophile cells appear in the cornea. This occurs, of course, only with exposures much longer than those used for therapeutic purposes. Even a slight abiotic reaction over a large area of cornea is intensely painful. It is the real basis of photophthalmia or snow blindness and may occur in typical form after accidental exposure to the flash of an electric arc.

It was formerly believed that snow blindness was due to the effect of ultraviolet light on the retina. From what we now know of the absorption of ultraviolet by the cornea and lens, it is apparent that only the longer ultraviolet rays between 3,200 and 4,000, and only part of these, ever reach the retina, and changes in the retina as a result of these rays have not been shown to occur experimentally. The retinal changes produced in rabbits by Birch-Hirschfeld were chiefly in eyes from which the lenses had been removed, and after much longer ex-

posure than is ever used clinically. Large doses of infra-red rays, on the other hand, may cause injury to the retina, and this is what occurs occasionally after looking at an eclipse of the sun, when atrophic changes in the central retina may later be seen with the ophthalmoscope.

The ultraviolet rays which pass the cornea may, in large doses, have the same effect on the epithelium of the lens capsule as on that of the cornea, and Duke-Elder warns against this in using phototherapy. The only clinical reports of cataract after phototherapy, however, of which I can find record are the two cases of Scheerer, and in these cases some x-ray treatments had also been given. It has been shown in the clinic of Vogt that very large doses of ultraviolet are tolerated by the lens without any opacity developing. In the same work, however, it was found that the infra-red rays which pass the cornea did produce lens opacities. It is to guard against this that the source of light used for phototherapy must be seriously considered.

Sources of Light.—General Irradiation.—For general irradiation of the body, the larger mercury vapor arc lamp is usually used, in a quartz tube. Types of this are the Jesionek light, a light described by Duke-Elder [1] which, with the addition of a screen and quartz applicator, is also suitable for local applications to the eye, and the air-cooled mercury quartz lamps, which are now being used rather extensively, especially by pediatricians, and which Koeppe has used. In Copenhagen, where the Finsen iron arc light was first used for tuberculosis, a type of large carbon arc has finally been selected as the one whose spectrum most nearly approaches that of the sun, and this is being used for general irradiation.[2] The object of this treatment is to produce a mild skin reaction, which has been shown to increase the bactericidal power of the blood, and so it is of value especially in tuberculous conditions and phlyctenular keratitis. In the technic used at Moorfields Hospital, one-third of the body surface is irradiated at each sitting with the mercury arc lamp, the dose being found which will produce a slight erythema, and this is repeated on other areas two or three times a week. After fifteen such treatments, a carbon arc light is then used which is richer in the long ultraviolet rays, and has a more penetrating effect. Five treatments with this are given, and after two to three weeks of rest, another course is given if necessary.

Local Irradiation.—For local treatments to the eye with ultraviolet light, Duke-Elder uses a mercury vapor arc slitlamp apparatus, with a quartz lens system; Koeppe, the water-cooled mercury quartz lamp, a small mercury arc in a water-cooled quartz container, with a quartz applicator. The light which is used in most European clinics, and which I have used in most cases, is the Birch-Hirschfeld irradiation lamp, a carbon arc, with a filter of uviol glass, and a quartz lens system, one lens of which is movable, so that a fine bundle of light can be

focused on the corneal lesion (Fig. 1). A quartz cell containing 0.5 per cent copper sulphate solution was used by Birch-Hirschfeld to remove the infra-red rays. This absorbs some of the ultraviolet rays, all, in fact, below 3,050 A°. Hence distilled water in the cell, which has the same effect on the heat rays, is to be preferred.

Uviol Filter.—Since the uviol filter removes some of the infra-red rays, I have often used the lamp without any other filtering solution and have never seen any damage to the cornea from the slight heat

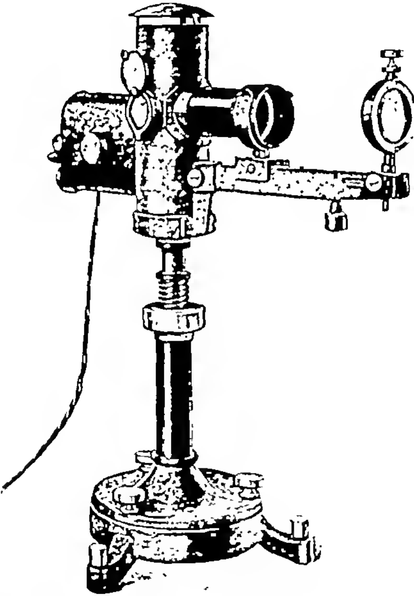

FIG. 1.—Birch-Hirschfeld Irradiation lamp with uviol filter and quartz lens. (Cell for distilled water not shown.)

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effect produced, which may itself have some beneficial effect. The uviol filter removes most of the visible rays which produce dazzling rays, transmitting only a narrow band of visible rays in the blue-violet, the effect of which is rather to decrease photophobia and corneal sensitivity. Figure 2 shows the spectrum of this light. Without any filters it transmits a uniform band down to 2,300 A°. With the uviol filter

FIG. 2.—Spectrum of Birch-Hirschfeld lamp. a, Arc light without filter; b, arc light with uviol and copper sulphate filters; c, arc light with uviol filter.

the shorter wavelengths are absorbed, but a considerable amount of ultraviolet down to 2,850 A° is transmitted. Other filters, such as some of the Corning glasses, or Wood's filter of nitrosoamino-aniline, transmit more ultraviolet, and attempts are being made to find a system of filters with which the amount of ultraviolet can be varied satisfactorily. The amount of ultraviolet emitted by the light itself is much affected by the carbons themselves, carbons cored with nickel, aluminum, cobalt or iron being especially rich in ultraviolet.[3] In the arc used in this work, carbons with iron cores were used. With this apparatus, as at present used, the light is focused on the lesion for five to ten minutes, and should be kept in focus by the surgeon or a trained assistant, as slight movements of the head or eye will otherwise remove the lesion from the area of effective radiation. Treatments are repeated once or twice a day.

Visible Rays.—Another method of phototherapy utilizes chiefly visible rays, which penetrate the media and are effective in lesions of the posterior segment. For this, the arc light, with Henker's filters of crystal violet and copper sulphate solution, is used. Koeppe reports good results from this method in 200 cases of tuberculous iridocyclitis, and in several cases of periphlebitis of the retinal vessels and choroiditis.

I have had no experience with this method of treating deeper lesions, and believe the evidence in favor of its use is not nearly so convincing as that in favor of ultraviolet irradiation in the types of condition to be described.

Comparative Results from Use of Various Lights.—Phototherapy was first used for the treatment of tuberculous eye diseases and phlyctenular keratitis in scrofulous children, following the work of Rollier and of Fleming and Krusius on exposure to sunlight in high altitudes. In these conditions, general light baths with the mercury vapor arc have proved of definite value. Stock, Koeppe, Duke-Elder and many others have reported rapid clearing up of eye lesions during the general reaction so produced, so that light baths are now a part of the routine treatment of phlyctenular keratitis in many clinics.

Tuberculous Iridocyclitis; Sclerosing Keratitis.—In tuberculous iridocyclitis and sclerosing keratitis, supposed in most cases to be due to tuberculosis, local applications of light have also been used. Koeppe's 200 cases of iridocyclitis, which have been mentioned, were treated with an apparatus which depended chiefly on the visible rays. Schanz used his arc light with uviol filter for similar conditions. Both Stock and Duke-Elder, however, report that no definite results are obtained by local phototherapy in tuberculous iridocyclitis, although Duke-Elder believes a trial of such treatment is justified where tubercles are confined to the iris. Stock and Gilbert have seen good results in sclerosing keratitis.

Lupus of the Lids; Conjunctiva.—Lupus of the lids and conjunctiva was first treated by Lundsgaard with the Finsen light, which he found superior for this purpose to the mercury vapor lamps because its spectrum contains more of the longer ultraviolet rays, so that a deeper effect is produced. The cornea was protected by cotton and the light applied to the everted lids, which were made anemic by pressure with a quartz applicator. Treatment lasted one to two hours, producing a second degree erythema with membrane formation. The water-cooled mercury quartz lamp requires much shorter exposures, and good results have also been obtained with it. Axmann used a mercury vapor arc with success in similar cases. He did not protect the cornea, and saw corneal opacities clear up under the irradiation.

I have used general light baths in severe cases of phlyctenulosis, sclerosing keratitis, tuberculous iridocyclitis and iridocyclitis of unknown origin. I believe they have been of distinct value in clearing up these obstinate conditions, and have been encouraged to make use of them more frequently. Like foreign protein injections, light baths often seem to produce a sudden shower of antibodies in the blood, sufficient to start the healing process. Naturally other methods of treatment are not neglected in these cases.

a

Trachoma.—Lundsgaard[4] submitted 109 eyes with trachoma to treatments with the Finsen light by much the same technic. He reports that many were cured after one or two applications, old cases with the disease deep in the lids being among those cured. In some cases, more treatments, as many as seven, were necessary. Isaak treated 22 eyes in the same way with good results, the follicles often disappearing in one week. Mohr and Baum and Chotzen and Kuznitsky used the water-cooled mercury quartz lamp with a special quartz applicator the shape of the lid, backed with metal so that the cornea was protected. In early cases, the results were much better than when the ordinary treatment was used, but in cases with extensive scar formation the effect was not deep enough. Marked clearing of the pannus was seen in many cases. Lundsgaard later (1918) reports that with the Finsen light, the length of treatments need be only 20 to 30 minutes, and that two treatments often produce healing. In my hands treatment of trachoma by irradiation has been disappointing and I believe it is now seldom employed.

Serpent Ulcers.—The treatment of serpent ulcers by light was begun by Hertel, *who used a magnesium light in 26 cases.* Two-thirds of these cases healed with much slighter scarring than was shown in similar cases treated by other methods. Schanz, in 1913, reported on the use of a carbon arc and also the quartz lamp, both of which delivered light of short enough wavelength to kill bacteria in the cornea. While his results were good, he did not believe they surpassed those

obtained by other methods, and gave up this form of treatment in favor of optochin.

His arc light with uviol filter and quartz lenses was in its essentials much the same as that used by Birch-Hirschfeld. This author [5] has been a most enthusiastic advocate of phototherapy for serpent ulcer, and considers it the treatment of choice, saying that it brings about healing in the shortest time with the least scar formation. Up to 1924, he reported 280 cases treated in the Königsberg Clinic, with 8.5 per cent of eyes lost. Hoffmann [6] reports on 190 cases treated since then, with only 4.6 per cent of eyes lost. Before the use of phototherapy, the losses averaged 32 per cent.

The arc light with uviol filter and quartz lenses was used for treatments of four to ten minutes, given once or twice a day. Fluorescein or rose bengal, 2 per cent, is first instilled into the sac to stain the cornea, as these dyes are believed to sensitize bacteria to the action of light. Birch-Hirschfeld advises using rose bengal for the first treatments, since it has the greatest effect on the organisms, then fluorescein, and finally, when there is delay in epithelization, rose bengal and short applications of light (3 minutes). Some interesting experimental work has been done by Passow [7] on these "sensitizers." Exposing plates inoculated with *Staphylococcus aureus* to the arc light, he found that without sensitizers, 120 seconds were required to kill the organisms, while when fluorescein was first used, the organisms were killed in 30 seconds, and when 2 per cent rose bengal was used, in 10 seconds. With a Hammer lamp, which transmits chiefly visible rays, and rose bengal, the organisms were killed in 10 seconds, but without the rose bengal this light was without any effect.

Much the same results were obtained when organisms were exposed in fluid of various depths, the Hammer lamp and rose bengal being the only combination which could kill organisms in layers 8 mm. deep. In pus the arc light with rose bengal was effective only in layers 0.1 mm. thick. In experimental corneal ulcers produced by *B. suisepticus*, irradiation with the Hammer lamp and rose bengal produced better results than the other methods which were tried, and seemed to justify the belief that such treatment in serpent ulcer could have a bactericidal effect.

Bactericidal Effect.—Planck states that sensitizers increase the bactericidal effect of visible rays, but have no effect on ultraviolet rays. This opinion seems to be confirmed by Passow's results, which apparently depended chiefly on the visible rays. Gilbert reports excellent results in serpent ulcer with the Birch-Hirschfeld lamp, which has made paracentesis and the cautery unnecessary in his cases. Stock, however, who has tried the same light in various conditions, reports no good results in serpent ulcer. Passow's demonstration of the enormous effect of a very thin opaque layer of pus in diminishing the effect of light would suggest that a bactericidal effect would be very difficult

to obtain in a serpent ulcer when the bacteria were lodged in the partially opaque cornea and were covered by a layer of exudate.

HERPETIC KERATITIS.—In herpetic keratitis, including dendritic ulcer and allied conditions, however, the virus affects the superficial layers and here, as would be expected, good results are reported by phototherapy. Stock reports almost unfailing success in these conditions, one treatment of five minutes often being sufficient. Peppmüller reports good results in severe cases. Of other forms of keratitis, phlyctenular keratitis has not usually shown a favorable response to local light treatments, while it does usually respond to general treatment. Interstitial keratitis has not usually responded well, although Hensen reports good results in the avascular form by the use of the air-cooled mercury quartz lamp locally for short exposures (one-fourth to one minute). Tuberculous keratitis has done well under treatment in the hands of Chotzen and Kuznitsky and others. Stock reports one good result in rodent ulcer.

BLEPHARITIS.—Blepharitis which does not respond to the usual methods has been treated by Duke-Elder with the mercury vapor slit-lamp with good results, and by Poyales with the carbon arc light.

Results from Use of Uviol Light.—Fifty-three cases were treated by the author with the uviol light.

SERPENT ULCERS.—The few serpent ulcers which were given phototherapy were also given the usual forms of treatment, including applications of optochin and trichloracetic acid and delimiting keratotomy. Their course differed in no way from that of other serpent ulcers, except that the pain and photophobia were usually relieved for some time following each treatment. In very early serpent ulcers, none of which were seen in this series, phototherapy might be effective and would cause a minimum of damage to the cornea. Perhaps better results would be obtained by employing, as Kubik in a personal communication has advised, very long exposures, up to 15 minutes twice a day.

CORNEAL LESIONS.—The most marked effect of phototherapy was seen, as might be expected, in superficial corneal lesions, such as herpetic or dendritic ulcers, which tend to spread over much of the cornea without involving the deeper layers. Here treatment by strong caustics or by paracentesis has, in my experience, been harmful, as apparently offering a foothold for the herpes virus on necrotic tissue, and allowing a deeper involvement of the cauterized areas. Fifteen such cases were given phototherapy, an exposure of three to five minutes being given every two days, until the ulcer ceased to stain with fluorescein. Rose bengal or fluorescein was used before treatment in all cases. The number of treatments required varied from four or five in mild cases to twenty-five in one case which showed several recurrences. All cases healed with a thin scar allowing useful vision, and although there were

recurrences in several, these responded to the same treatment. In most cases, the time required for healing was considerably shorter than that which would have been expected from the type of ulcer present. The most marked effect was seen after the first few treatments, and in five cases healing occurred after two to four treatments, with almost negligible scar formation. (In one case, this occurred after one treatment.) Later treatments seemed to have less effect. While this may be explained by the assumption that the herpes virus was deeper seated in these cases, a distinct impression was formed that the cornea became tolerant of the light and ceased to be stimulated by it, or that the resistance of the virus to light was increased.

In nearly all these cases, the effect of light treatments on the pain and photophobia was marked from the first. It seems remarkable that a patient suffering from intense photophobia can be made to look fixedly at the uviol light for five minutes with very little discomfort, and that he will afterwards be able to endure ordinary light much better than before.

Epithelial Dystrophy.—Another condition which would seem especially adapted to phototherapy is epithelial dystrophy of the cornea, and in the milder forms of this, showing no gross bleb formation, but containing, as revealed by the slitlamp, countless minute areas which stain with fluorescein, some good results were obtained. Six such cases were treated, and although dionin was also given, they seemed to respond more rapidly than those given dionin alone. One case healed in thirteen days after five treatments, and the tension, which had registered 24 Schiötz, decreased to 15. One case, which developed during iritis, healed in ten days after seven treatments.

In one case of the severer form, with some deeper corneal opacities, the light treatment was without effect. Two cases of the probably allied condition of recurrent corneal erosion, in which large blebs were present, were given one to three treatments, but without marked effect, and abrasion and bandage were resorted to. No other reports have been seen of the treatment of epithelial dystrophy by phototherapy. Recent reports by Post and Green indicate a definite beneficial effect of phototherapy in typical epithelial dystrophy. In the apparently very favorable cases, it is impossible to state that the good results were due to phototherapy, since some cases respond very well to dionin. Here no organisms or virus can be made responsible for the condition, so the apparent effect of phototherapy must be due to a stimulation of the epithelium.

Corneal Scar.—Of types of ulcer other than serpent ulcer and herpes corneae, a good effect was obtained in two cases of corneal scar with degeneration and ulceration over the scarred area, which healed after three and four treatments respectively. In one case of phlyctenular ulcer, the effect was at first good, especially on symptoms, but the condition recurred during treatment. In another, no effect was noted.

SCLEROSING KERATITIS.—Because of the favorable reports of Stock and others on its use in tuberculosis of the anterior segment, phototherapy was tried in three typical cases of sclerosing keratitis probably due to tuberculosis, because of positive tuberculin reactions and negative results of a search for other causes. One very severe case did not return for more than one treatment. The other two, however, showed a quite distinct improvement on phototherapy. In these cases, where we do not know whether the tubercle bacillus is present in the cornea or sclera, and where a good deal of opaque tissue is opposed to the penetration of light, the assumption of a stimulating effect of light, producing a dilatation of the capillaries and bringing in a new supply of antibodies, seems the only one which will account for the apparently marked improvement.

MOOREN'S ULCER.—In one case of Mooren's ulcer, the progress of the ulcer stopped during the first three treatments, but then began again in spite of further treatments. No effect was observed in two cases of extensive corneal erosion, one from lime burn and one from acid.

TRACHOMATOUS ULCERATION.—Of the five cases of trachomatous ulceration treated, three responded very favorably to phototherapy. Two of these cases had resisted all other treatment, and the light appeared to be the factor which turned the scale in favor of healing. In one of these, treatments were given twice daily for three days.

BLEPHARITIS.—The six cases of blepharitis subjected to light treatment were very severe ones, which had shown no response to yellow oxide of mercury, correction of refraction, and systemic treatment. Four responded very favorably, after twelve, three, six, and seven treatments, respectively. In two an autogenous vaccine was given at the same time, but in the other two the light was apparently the only factor responsible for cure. The uviol light was focused on the same area and moved back and forth for the same length of time. While the results in these cases were apparently very definite, I do not insist upon them, as I have found two or three proper treatments with x-ray to be as effective, if not more so, in obstinate cases, and this treatment is less time-consuming for the patient.

In using the uviol light, I have never seen any harmful effect on the lens or deeper structures, nor has the lesion treated ever been made worse by such treatment.

Results from Use of Mercury Vapor Arc.—Twenty-eight cases were treated by the mercury vapor arc. In this series two sizes of quartz applicators were used in the treatments, one of eight millimeters for treating the lids and conjunctiva, and a small one of two and one-

half millimeters for small corneal lesions. In later work, the conical applicators described later were used. Through fear of causing painful light reaction, the dosage first used was small, but it was found that 45 seconds could be safely used on corneal lesions, repeated, if necessary, on other areas of the same cornea, two to three minutes to the conjunctiva of one lid and fold, and to the whole lash border of each eye. The expected symptoms of light ophthalmia did not materialize. Only a few patients complained of burning after treatments, and in only one case were these symptoms severe enough to cause the treatments to be discontinued. One patient developed two punctate corneal infiltrations after his lids were treated, but these healed in 24 hours. The conjunctiva was treated by everting the lid and keeping the cornea under the opposite lid.

The best results were obtained in blepharitis, two cases being practically healed after one treatment, and the other much improved. One case of dermatitis was entirely relieved of itching after one treatment, and the lids became smooth. The reaction around severe deep hordeolum seemed to subside rapidly after light treatment and the sty opened spontaneously earlier than was expected. One subsided after two treatments without becoming purulent. Chronic conjunctivitis with blepharitis responded well when light was applied to both the conjunctiva and lash border.

While the Birch-Hirschfeld lamp or Duke-Elder's mercury vapor arc alltlamp is probably the most effective instrument for applying light to corneal ulcers, the ordinary mercury vapor light or an air-cooled light with quartz applicators is almost necessary for the treatment of the conjunctiva and better for treating blepharitis, as larger amounts of effective ultraviolet may be delivered over larger areas than with the former instruments. I believe the cornea may also be treated effectively and safely with the mercury vapor light, by using small applicators and directing the light away from the pupil. The attachments for the use of this light made for Dr. Coulter of the Physical Therapy department, Northwestern University (Fig. 3), are convenient for limiting the light to a desired area of cornea or lids, the apertures for the cornea varying from 1.5 to 5 mm. in diameter and being 3.5 cm. from the light, and the one for the lids and conjunctiva being a slit 5 mm. wide and 3 cm. long. With these, the use of quartz applicators, which make the amount of light delivered a variable quantity, is unnecessary.

Dosage.—The question of dosage, which is important, depends on several factors. When most of this work was done, no satisfactory system of measuring dosage had been arrived at. The time of exposure for the uviol light recommended by Birch-Hirschfeld was accepted, since with this instrument large doses could be given without producing erythema or corneal erosion, and it was thought that

some of the effect was probably due to heat rays and to visible rays acting with a sensitizer. With the mercury vapor arc light, experiments on the rabbit's cornea, and cautious clinical use of the light, indicated 45 seconds for the cornea and two minutes to the lids as a safe dose. Mercury vapor arc lamps vary considerably in the amount of light delivered, and individual patients also vary in their reaction to given amounts. It now seems safest to try out each patient with the lamp to be used in order to find the time necessary to give a skin erythema,

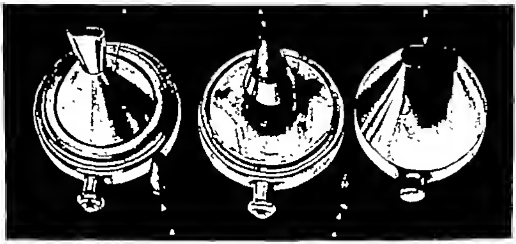

Fig. 3.—Coulter's applicators for using the mercury vapor arc light. *A*, corneal applicators of 1.5–3–5 mm. diameter and holder. *B*, applicators for treating lids and conjunctiva.

using 75 per cent of this as the initial dose for the cornea, and 75 per cent for each lid border or the conjunctiva of the lid. With a powerful light source, such exposures require considerably less time than the doses mentioned above. Even these doses may cause moderate reaction with marked photophobia, and the feeling of a foreign body persisting 24 to 36 hours.

Summary Of Phototherapy

I. Beneficial effects of phototherapy, especially with ultraviolet light, may be explained in four ways: by a direct bactericidal effect, by stimulation of the epithelium, by improved nutrition from the hyperemia produced, and by an increase in the antibodies of the blood.

II. General light baths with the mercury vapor arc are of great benefit in phlyctenular keratitis and in ocular conditions due to tuberculosis.

III. Local phototherapy is of benefit in superficial corneal ulcer, tuberculosis of the cornea and conjunctiva, and blepharitis.

IV. Herpetic lesions show the most marked effect of such treatment, some healing after one or two treatments.

V. No marked results were seen in serpent ulcer in this series, but the reports of others would seem to justify a trial of such treatment, especially in early cases, other forms of treatment not being neglected. The length of treatment in these cases might well be increased to ten minutes twice a day.

Diathermy

Diathermy, medical and surgical, has not attracted so much attention from ophthalmologists as has phototherapy, if one is to judge by the relatively small number of reports in the literature. A recent handbook by Monbrun and Casteran [8] presents evidence of distinct advantages for these methods in a number of ophthalmologic conditions. These authors point out the danger of generating intense heat near the eye and state that it should never be employed for the treatment of intra-ocular diseases. Medical diathermy has been shown experimentally to increase intra-ocular tension and so should never be employed in glaucoma. The forms of apparatus commonly employed are not suitable for use in ophthalmology, where much weaker currents must be utilized. A special milliamperemeter recording currents below 500 milliamperes is necessary and this current should ordinarily not be exceeded. These authors describe (Figs. 4 and 5) a special ebonite handle with applicators in the shape of delicate needles, hooks and blunt instruments suitable for surgical diathermy about the eye, and a set of metal eyecups fitting over the closed lids to be used for a more diffuse heat effect (medical diathermy). The lids are controlled by a glass lidholder. While some such special equipment for ophthalmic work is necessary, this need be neither cumbersome nor expensive, and with the precautions mentioned above, certain procedures may apparently be carried out very conveniently and with perfect safety.

Trichiasis.—One condition in which there is no doubt of the efficacy and convenience of diathermy is that of trichiasis, where a few lashes must be destroyed. The generally used method of electrolysis, while effective, required that the current be continued 30 seconds for destruction of each lash follicle, and in spite of careful local anesthesia, can seldom be accomplished without some pain of a very unpleasant kind, with a tendency for the patient to make involuntary jerking movements. Surgical diathermy requires only one second for the destruction of each lash, and after infiltration with novocain the procedure is painless. Monbrun and Casteran advise the use of a single sharp needle, which is inserted in the follicle, as the active electrode, the indifferent electrode not being connected. A current of only 150 milliamperes is used, for one second, and the current is shut off with the foot pedal before the needle is removed, as otherwise a spark will be produced. If the lash resists gentle traction with the lash forceps, the coagulation has not been sufficient and should be repeated. A

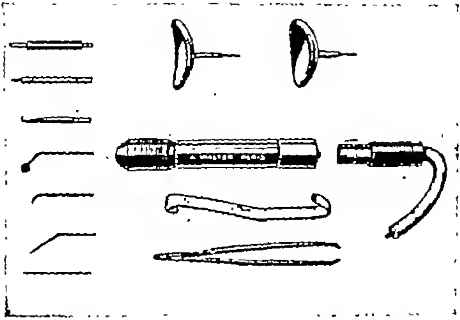

FIG. 4.—Electrode holder and glass lid retractor for diathermy. (From Monbrun and Casteran.)

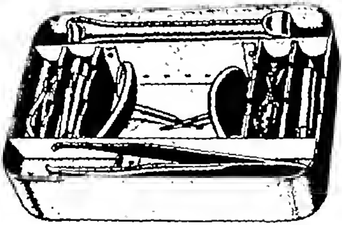

FIG. 5.—Diathermy apparatus in box for sterilization. (From Monbrun and Casteran.)

number of lashes may be removed in this way at a single sitting, but if more than six to eight inturned lashes are present, it will be more convenient to perform a plastic operation. The same method may be employed for the corneal portion of a pterygium but is more complicated than surgery.

Chalazion.—Chalazion of the ordinary type is also more simply attacked by surgery, but where a small chalazion is present on the free lid border, rather a delicate surgical procedure is required with the use of a stitch. Here diathermy presents distinct advantages because of the slow necrosis produced, with resulting delicate and practically invisible scar. Here the ordinary method is employed, with a large indifferent electrode under the patient, and a small needle as the active electrode. This is passed into the chalazion after infiltration and a current of 200 to 300 milliamperes is used for one second, this being repeated two or three times with the position of the needle slightly changed, according to the size of the chalazion.

Division of Cicatricial Bands of Orbit.—Another use of surgical diathermy which seems important, if the experience of these French observers is confirmed by others, is the division of cicatricial bands of the orbit which prevent the wearing of an artificial eye. When these are divided surgically, adhesions invariably occur, so that free grafts of skin or mucous membrane are necessary. On account of the delicate and nonretractile scars formed after electrocoagulation, it is claimed that such bands may be simply coagulated with a needle-hook, using the same method with two electrodes. The bands should not be cut, but only sufficient current and traction should be used to turn them white, usually two to three seconds of 200 to 300 milliamperes being sufficient. No sutures or dressings are necessary. A temporary small prosthesis may be worn immediately afterwards and a permanent one made after 15 days, when elimination of the necrotic tissue is complete. The same procedure may be used for neoplasms of the lids, using the electrode knife, with the advantage that a "barrage" can be made at the periphery by partial coagulation which will prevent the escape of tumor cells from the diseased area. In many cases, however, excision of the tumor with plastic repair is preferable.

Large Tumors.—In large tumors requiring evisceration of the orbit, surgical diathermy * has long been used, because such coagulation blocks avenues of extension and may be performed with very little bleeding. For this purpose the use of two active electrodes is advantageous (see Fig. 6), the indifferent electrode being replaced by a branched handle carrying two small electrodes a short distance apart. An intense heat is generated only in the zone between these two electrodes. This allows complete destruction of neoplastic tissue without danger of bony necrosis which may occur after using the other meth-

* Editor's Note: The term surgical diathermy as used here is synonymous with the term electrosurgery used in other chapters.

ods by which the zone of radiation cannot be so accurately localized. *A current of slightly over 500 ma.* is necessary. Monbrun and Casteran recommended that such large growths be destroyed in several sittings.

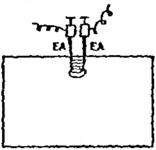

FIG. 6.—Diagram of surgical diathermy with two active electrodes. (From Monbrun and Casteran.)

This possibility of dividing the operation without fear of causing extension is one of the great advantages of the method, as after the slough has separated, one can judge the necessity of further intervention.

Orbital Cellulitis.—The indications for medical diathermy in diseases of the eye are by no means well established. Perhaps the only condition in which it has advantages is the occasional orbital cellulitis which does not localize well enough for incision to be effective. Here a large sheet of tin or aluminum is moulded to cover the region which is used as the active electrode, the still larger indifferent electrode being beneath the patient. It must be remembered that the larger the active electrode, the less heat is generated at any point, so that this method avoids a degree of heat dangerous to the eye, provided that only 200 to 400 ma. be employed, and the current reduced whenever the heat becomes uncomfortable to the patient. Treatments should begin with 5 to 10 minutes and should be increased to not over 25 minutes, being repeated every two to three days. Marked relief from pain may result from such applications in the neuralgia of herpes zoster, and Monbrun and Casteran report good results in certain corneal ulcers, especially those following facial paralysis. It seems best to follow their advice not to employ diathermy in intra-ocular diseases, in spite of reported good results in relatively small numbers of cases of various conditions by Löffler and Wellisch [8] and others. These authors employed the method in glaucoma, in which experimental evidence, according to the French authors, definitely contra-indicates it.

Since the surgical treatment of retinal detachment was shown by Gonin to be practical, most authors have employed some form of electrocoagulation for this operation. The area surrounding the retinal tear which is almost invariably present is surrounded by areas of coagu-

lation. This is administered either through the exposed sclera by the flat or ball-shaped electrodes of Weve, or directly into the choroid by the pins of Safar, Walker or Weve, which are forced through the sclera under a current of 60 to 75 ma. For surface coagulation of the sclera which is often employed with perforating diathermy, a current of 150 to 200 ma. is employed, each area being treated for five to six seconds. For the detachment operation the apparatus of Walker is satisfactory, but others generating higher current for electrosurgery may also be employed.

The use of high frequency currents (electrolysis) has been employed for treating retinal detachment by Vogt, Walker and others. Very careful localization of the retinal tears is necessary, their edges being touched directly with fine needles generating high frequency currents of very low amperage, seldom over 1 to 2 ma.

Instruments.—It is regrettable that instruments for diathermy are not standardized so that a stated dosage will be the same with all instruments. On account of variations in voltage and other factors, the doses in milliamperes given above will have only a relative value, indicating to the physician a very weak or very strong coagulating effect desired, from which he must calculate dosage with the machine at his disposal. Fortunately the immediate local effect of the electrode on the tissue furnishes the best evidence of the total dosage required.

The number of cases in the private practice of the average ophthalmologist really suitable for diathermy will be too small to warrant his obtaining the full equipment necessary. Such equipment, however, is now available in most modern hospitals and clinics, and the eye department of many such institutions could easily obtain the slight additional equipment necessary to treat ophthalmologic cases. Hence the modern ophthalmologist will wish to be prepared, so that he may personally supervise the use of medical diathermy or employ surgical diathermy in the occasional cases where they are definitely indicated.

The Thermophore

A device for the accurate application of ordinary heat to lesions of the eyes and adnexa is the thermophore, described some 15 years ago by Shahan. This is an electrically wired unit which may be adjusted to any desired temperature, with metal applicators to fit small lesions of various shapes and sizes. Post [10] has recently summarized some of its uses, emphasizing especially its effect in deep infiltrations of the cornea which are not accessible to antiseptic agents. Here a temperature of 63 ° C. (145.4 ° F.) is applied for one minute. Small granulomas of the free lid border which are probably of the same nature as chalazia yield readily to the same treatment, and xanthelasmas are sloughed off with a minimal scar following one or two such applications, he states. This instrument is not so widely

used today, apparently, as it was soon after the perfected model appeared, and this is probably because the results in serpent ulcer, for which it was especially advocated, proved disappointing.

X-Ray and Radium

In the use of x-ray and radium, precautions against harmful effects on the ocular structures are even more important than in the forms of physical therapy previously discussed. The hard roentgen rays penetrate the lids and cornea and are absorbed in large part by the lens, where the resulting reaction has in a number of cases produced cataract. This has usually followed large doses given for carcinoma of the lids or for lupus. Stock [11] reports such a case in which glaucoma also developed following one irradiation of 110 per cent skin erythema dose, and another following repeated small doses. A fairly large number of other cases have been reported and we now know that small repeated doses have a cumulative effect, and that the lens changes may not appear for long periods after the irradiation, often not for one and one-half to three years.

Individuals vary greatly in their susceptibility to x-rays, which must be remembered in considering the absence of lens changes observed by Birch-Hirschfeld after intensive irradiation of animals and the statement of Rados and Schinz that 150 per cent skin erythema doses were tolerated by the eye without reaction in their cases. Damage to the lids and cornea is also possible, the permanent loss of cilia being a not uncommon and sometimes necessary result of irradiation for carcinomas of the lids. Stock quotes, besides his own, several cases of glaucoma apparently resulting from x-rays.

Where the lids or orbit are to be treated, the globe should always be protected. Stock advises the use of Müller's lead-glass prostheses, which cover the corneas like artificial eyes. I have been informed, however, by roentgenologic colleagues, that the amount of lead in these prostheses is insufficient for protection, and have used sheets of leadfoil moulded in the same manner. The glass reform eye filled with mercury which was used by Rohrschneider [12] gives a layer of mercury ample for protection, and is comfortably worn (Fig. 7). Protection of the globe is not possible when neoplasms of the cornea or bulbar conjunctiva are treated, and hence surgery is more practical for these when possible. Small carcinomas of the lids, also, when seen early, may usually be excised completely with primary plastic closure of the defect, the cosmetic effect being as good and the time consumed much less than is required for irradiation. A recent patient with carcinoma in the middle of the lower lid chose radium treatments instead of surgery, and is apparently cured, but with a resulting defect involving half the lid which is at least twice as extensive as the area which would have been removed surgically, and will be twice as

difficult to close. When neoplasms involve the inner or outer angle, however, or are adherent to the bony orbit, removal presents a much more difficult problem and here radium or x-ray is definitely indicated. Large orbital neoplasms adherent to the orbital walls are often treated by evisceration of the orbit, followed by radium or x-ray. Regaud and associates [13] have shown that such previous surgery increases the danger of bony necrosis from subsequent irradiation, and claim better results in cases where no surgery has been attempted. In treating such conditions, large amounts of radium or modern x-ray

Fig. 7.—Protective reform eye holding mercury. (Made by Mager and Gougelman after Rohrschneider.)

equipment are necessary and they should be undertaken only by men who have had a great deal of experience in the treatment of malignancy. Whether surgical diathermy should replace irradiation in many of these cases cannot yet be decided.

Advantages of Radium and X-Rays.—Kumer and Sallmann [14] have summarized the respective advantages of radium and x-rays. The rays of radium are much more penetrating than x-rays, 10 cm. of lead being necessary to absorb the former, as against 3 to 5 mm. of lead for the latter. While it is thus more difficult to protect the globe against radium, the small tubes of radium or its emanations may be so placed as to exert most of their effect on the new growth and little on the eye, and hence radium is to be preferred for small tumors of the lids. It may be inserted into large orbital tumors in the form of radium needles, or as seeds of the emanation which are left in the tumor till their activity is exhausted. In these ways every part of the orbit may be reached, and the danger to the globe, the function of which is in any case usually doomed, need not be considered. Certain neoplasms are more sensitive to radium than to roentgen rays. In neoplasms covering large areas of skin, however, x-rays have the advantage of covering the whole area uniformly and since the rest of the skin and the globe may be protected by lead, the irradiation may be

much more accurately confined to the desired area. In new growths of the bulbar conjunctiva and cornea, better results have been reported from the use of radium. The freedom of the globe from damage in most of these cases is apparently due to the small dosage necessary for the destruction of these growths and to the fact that the hard rays which penetrate the globe require for a harmful effect five times the dosage of the soft rays, which are most effective in destroying the tumors.

Harmful Effects.—The harmful effects of overexposure of the eye to radium are practically the same as those produced by x-rays. About the same number of cases of keratitis, cataract, and glaucoma, most of which are mentioned by Kumer and Sallmann, have been reported after radium as after x-ray treatment. The dosage which is tolerated is apparently, according to these authors, somewhat higher than that of x-rays, 100 per cent skin erythema dose being about the upper limit of safety for one application and 300 per cent for the total dosage divided over a year. The lids must be considered especially sensitive to radium, 60 to 70 per cent of a skin dose being sufficient to produce an erythema of this region and a full skin dose often causing considerable damage. The lash-border must be kept out of the field where possible. With x-rays, Stock cautions against a total of over 100 per cent erythema dose, unless the globe is protected.

Protection.—Although Kumer and Sallmann describe prostheses for the protection of the eye during radium treatments, they admit the impossibility of adequate protection by any filters and recommend protection by careful removal of the applicators to the proper distance from the globe by special devices. The only real purpose of the lead glass prostheses of Müller or the molds of paraffin placed under the lids as described by Hoed, Stoel and de Vries [15] is to hold the lids away from the globe and so increase its distance from the radioactive agent. Greater distance is obtained by mounting the tubes on wood blocks of various sizes or in the special wax-composition blocks now being used in most radium institutes (Fig. 8). Most of the irradiation therapy of eye diseases will naturally be performed by specialists in this form of treatment, and many details of dosage and technic must be left to their judgment. The ophthalmologist should, however, be familiar enough with the principles of roentgen and radium therapy to advise with the radiologist on his individual cases which often present problems of protection or attack with which the latter may not be familiar.

Conditions Suited to Treatment.—Vascular nevi about the lids are especially suited to treatment with radium. This is especially true of capillary hemangiomas, in which the cosmetic result is usually far

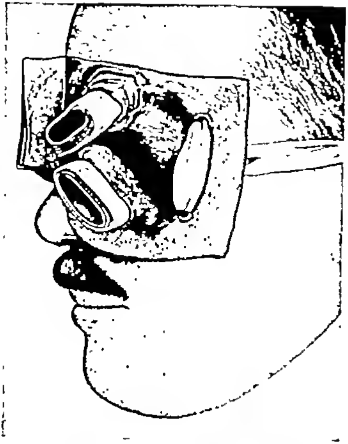

Fig. 8.—Wax prosthesis with lead filters for irradiation with radium at 3 cm. (From Kumer and Sallmann.)

Fig. 9.—Angioma before and two years after radium treatment. (From Kumer and Sallmann.)

better than can be obtained with surgery, and often almost perfect (Fig. 9). The earlier these cases are treated, the more readily do they respond, since the young vessels are especially sensitive to radium. Nevus flammeus, large blood cysts or hemangiomas supplied by large vessels do not yield so readily and some of these are better treated surgically. Xanthelasmas are usually easy to remove surgically, with practically invisible scars, and it is only in the case of unusually large ones that radiation will be considered. In spite of the favorable reports of many authors, Kumer and Sallmann consider them as not especially adapted to radium therapy. Carcinomas and sarcomas of the lids require no special discussion here, aside from what has been said as to the types suitable for irradiation (Fig. 10). Detailed case reports, with indications for and against roentgen

Fig. 10.—Carcinoma of the inner canthus before and 3 months after curettage and radium treatment. (Kumer and Sallmann.)

and radium therapy, will be found in the monographs of Kumer and Sallmann and of Stock, and in the article of Regaud and associates, previously referred to.

Blepharitis.—Among the ophthalmologic conditions in which roentgen therapy is especially useful is blepharitis of the more severe type which has proved refractory to the usual methods. Here two or three x-ray treatments will often entirely relieve a condition of years' standing. A technic for which I am indebted to Dr. J. Borghoff, of Omaha, Neb., has proved effective with my patients and has produced no harmful effects. The rest of the lids being protected by lead foil, the lid borders are exposed to a current of three milliamperes, with

six-inch spark gap, at *eight inches' distance*, for 40 *seconds* to one minute. This is repeated weekly and usually three treatments are given. This is from one-fifth to one-half of the epilation dose. Other authors advise one-third of a skin dose as a routine for this condition. The lashes have never been lost, even temporarily, in my cases. The same method of treatment is used for cases of chronic dermatitis of the lids and is equally effective. The smaller of these doses is usually sufficient for this condition.

Pituitary Tumors.—The treatment of pituitary tumors is of especial interest to ophthalmologists, and here the question of irradiation often comes up. The adenoma is the only form of pituitary tumor that is responsive to irradiation, this treatment being of no effect in the Rathke's pouch type of tumor or in cystic tumors, and of little effect in meningiomas. Where these latter types can be ruled out, a trial of irradiation may be made. In some cases, such a trial may give diagnostic evidence as to the type of tumor, and in cases in which the patient refuses operation, a trial of irradiation is indicated unless a Rathke's pouch tumor can be definitely diagnosed. Roentgen therapy is usually the only method of irradiation to be considered, since radium therapy cannot be directed to the site of the tumor without producing incalculable damage to the surrounding important structures. Only in the case of a tumor which has eroded the floor of the sella turcica, or where sellar decompression has been done, may radium be used through the sphenoid region in addition to roentgen therapy. The technic, as used on my patients by Dr. A. F. Tyler, is as follows:

Voltage	135 K.V.
Distance	40 cm.
Filter	5 mm. copper
Amperage	5 ma.
Time	40 min.

Such a treatment was giveo to each temporal area, with the tube directed to the sella turcica, a week being allowed between the treatments. After a month or more the treatment may be repeated.

In cases which show further visual loss in spite of this treatment, no time should be lost in resorting to surgery.

Brain Tumors.—In the case of brain tumors which are inoperable and are damaging the vision in spite of decompression, a trial of deep roentgenotherapy may be made with the possibility that the tumor's growth may be checked or that the resulting atrophy of the choroidal plexus will diminish the pressure from an internal

hydrocephalus. A form of dosage for this, also furnished by Dr. Tyler, follows:

Voltage	200 K.V.
Distance	50 cm.
Filter	0.75 mm. copper, 1 mm. aluminum
Amperage	4 ma.
Time	100 to 200 min.

This dosage is divided between two lateral areas and is estimated for each case by the modified Dessauer charts.

Intra-ocular Diseases.—The use of roentgen therapy for intraocular diseases, especially tuberculous iridocyclitis and choroiditis, must be considered as still in the experimental stage. Since the lens cannot be protected in such treatments, there is always some danger of producing cataract, although this has been avoided in most cases by the use of small doses. Scheerer and Stock, after trying larger and smaller doses, settled upon 15 to 20 per cent erythema dose, repeated after seven weeks, as the most effective dosage which could be safely used. The long interval is advisable to avoid the secondary reaction which often occurs after four weeks. Stock advises no more than a total of 60 per cent erythema dose in a year, divided into three or four applications. Stock and Scheerer, out of 38 cases, report some good results in very severe cases. The use of three-fourths erythema dose given during three weeks as advised by Gilbert, according to Stock's experience would seem to be too large, and with that of Braun and Herrenheiser, one-sixth to one-eighth skin dose, the interval of seven days is apparently not long enough to avoid a cumulative effect. These authors report three cases of tuberculous choroiditis treated with good results, but Stock has seen similar cases develop fresh lesions during treatment and considers the effect of the treatment in their cases as doubtful. Although, in the severe cases of tuberculous uveitis and sclerosing keratitis which have resisted other treatment, a trial of small doses of x-ray is apparently indicated, its use in ordinary iritis, as advised by Horvath, is certainly not necessary, as other perfectly safe methods are usually effective in these cases.

Vernal Conjunctivitis.—A very definite indication for the use of radium exists in the still little understood condition of vernal conjunctivitis. A number of these cases are relieved of their symptoms by adrenalin, by intravenous injections of afenil, or by desensitization to some specific protein. Others, however, are not so relieved, especially the cases with large flat papillae of the upper lid, and these

cases should be given an opportunity to try radium therapy, as many are relieved only by this means. I have used the technic recommended by Dr. Laura Lane of the Todd Memorial Institute, and in three very obstinate cases have seen almost entire relief from symptoms, with disappearance of most, if not all, of the papillae and their replacement by smooth scar tissue. Radium is much to be preferred to x-ray in these cases, the latter not having, apparently, the same effect on the condition. Loss of lashes has not occurred, in my experience, when the following technic, kindly furnished by Dr. Lane, was adhered to.

Method.—In the palpebral form the following method of using radium in vernal conjunctivitis has proved effective.

Amount: 15 to 20 milligrams of element or the same number of millicuries of radon are used with the following screening:

Platinum...... 0.05 mm.
Brass ....1.00 mm.
Rubber ....1.00 mm.

The platinum may be used as the casing or cover of the element contained in a needle form or as the screen of a radon tube. This platinum container is placed in a brass capsule and the whole is covered with rubber or dental dam.

Distance: This tube is placed at one centimeter distance from the closed lids. A piece of Columbian paste or gauze is placed between the tube and the lids to keep the radium at the proper distance.

Duration of Exposure: The duration of the exposure is from one-half to one hour, according to the age of the patient and the severity of the disease as well as the amount of radium used. The first dose is usually applied for only half an hour in order to judge somewhat the sensitivity of the patient.

Interval: The sitting is not repeated under 10 to 14 days, according to the response obtained and the severity and the duration of the disease. Three to four such sittings are given. It is often necessary to lengthen the interval between sittings to three weeks.

Direct Application: At the time of the above sitting, in addition to the radium applied through the closed lid, a direct application to the everted lid is made. No screen is used other than the platinum. The amount of radium used is preferably a 15 mg. platinum needle. This is sterilized by placing it for a few minutes in a 10 per cent formalin solution, followed by 70 per cent alcohol and then by sterile water which is wiped off with sterile gauze. A few drops of a one per cent cocaine or butyn solution may be used to make the everting of the lid less unpleasant. The needle is moved slowly across for three minutes, at a distance of two millimeters.

Rest Interval: After the third or fourth application, according to the response and the severity of the disease, a rest is given for two or

more months. Then a similar series of treatments is repeated. The interval between these treatments is two weeks. In the more stubborn cases which have lasted for years and in those cases subjected to much previous caustic treatment, it is well to give a third series some months later, particularly later in the winter.

Operation and Irradiation: When the papillae are very dense and cobblestone-like, much time will be gained and a more satisfactory response obtained by anesthetizing the palpebral conjunctiva and snipping off or rolling the papillae; then applying a five milligram varnish applicator plaque, screened with one millimeter of rubber, at two millimeter distance, for three to five minutes at a sitting. Sittings are repeated at intervals of two weeks for three doses. It is often necessary to follow this series by one of irradiation through the closed lids. The application of the platinum needle by the direct method may be used instead of the plaque, the exposures being slightly longer but not exceeding 10 min. A needle plaque, of one or five milligram needles, can be used.

Hypertrophic Bulbar Form: In the hypertrophic bulbar form of vernal conjunctivitis, the use of a 10 or 15 mg. platinum needle (0.05) for three to five minutes, at two mm. distance once in 10 days for three doses, is recommended. A second series of treatments may be given in a month using in this series one millimeter of rubber to screen the needle. The radium must be kept moving constantly above the area being treated so that an even distribution of the rays is obtained. Except in early cases, seen during the first year of the disease, screened applications through the lids will be necessary.

Quick,[18] of the Memorial Institute, reported the results in 82 cases of vernal conjunctivitis treated by irradiation, the largest series which I have found on record. His results were good, as 40 cases were apparently cured, 25 of these having been seen after one to nine years, and 32 were definitely improved. He recommends a technic quite different from Dr. Lane's, an "active deposit" of radium emanation collected on lead foil, which is placed under the lids. Two hundred to 400 millicurie minutes are used for each eye in a treatment, and only a few such treatments at relatively short intervals are advised. Since the preparation of such "active deposit" is possible only in specially equipped institutions, he suggests the use of plaques of the element prepared to fit under the lids, with protective metal back and handle, the element being held in place by shellac which gives slight filtration. He cautions against treatment through the lids, as involving danger to the lashes and as requiring the use of harder rays with the resulting danger of producing cataract, of which he has seen several examples. Local infections of the lid borders must be cleared up as irradiation in their presence is likely to be followed by corneal involvement. Repeated doses over long periods are also dangerous, he believes. He concludes that in spite of the good results obtained, radium should be reserved for cases in which all other methods have

failed, on account of the dangers, especially to the lens, inherent in its use.

Woods[16a] has recently described the use of radium emanations, tubes delivering almost exclusively beta rays being employed. Such preparations are so superficial in their effect and so free from deeper rays that, according to Woods, 50 times the erythema dose might be given without danger of producing cataract. He employs this method in vernal conjunctivitis and also in some chronic inflammations of the sclera and anterior uveal tract, apparently with success. It is especially recommended in tuberculosis of the anterior segment. The dosage with this method varies but in general the emanation from 1 Gm. of radium is applied for a total of 35 to 40 seconds, this being divided into four to six weekly doses. Such a course may be safely repeated after several months.

Intra-ocular Tumors.—In the case of intra-ocular tumors, glioma (retinocystoma) and sarcoma, the hopes aroused during the early days of irradiation therapy have only in small part been fulfilled. Here, however, the danger of such treatment to an otherwise doomed eye need not be considered a contraindication, and since a few definite cures have been reported, irradiation must be considered in certain cases. Naturally, where only one eye is affected, enucleation is still absolutely indicated. It is only in bilateral glioma, especially where the second eye is much less involved, or in sarcoma of the only seeing eye, where enucleation is decided against by the patient, that irradiation should be undertaken. In the case of glioma, this should be preceded by enucleation of the first eye, unless both eyes are equally involved. Of a fair number of gliomas in which irradiation has been employed, most have shown a temporary decrease in size of the tumor, followed by renewed growth and the usual outcome. Of those treated by radium and mesothorium, Kumer and Sallmann record only one, that of Schönberg, in which a cure was obtained with vision of 2/20 after 10 years, during which a cataract developed and was extracted. Schönberg used 144 millicurie hours, followed in six months by 456 millicurie hours, and again, after two years, by 3,036 millicurie hours, with filtration for the use of gamma rays. To this case must be added that of Benedict,[17] the patient being a child of four with a growth involving the retina from near the nerve forward almost to the ora serrata on one side. Six thousand milligram hours of radium were given, with treatments repeated after six months until 90,000 milligram had been given. The tumor disappeared, leaving only a flat scar and vision improved to 6/7. After five years lens opacities developed, reducing vision to 6/60, but there was no recurrence. The diagnosis of glioma was confirmed by sections of the enucleated first eye. While dosage must vary with individual cases, in general it may be said that gamma rays should be employed, and that the method of cross-fire irradiation, with the radioactive substance at 2 to 3 cm. from the eye, is to be preferred.

One-fifth skin dose daily every second day for six to eight treatments is recommended by Kumer and Sallmann, with further treatments after two to three weeks as indicated by the result obtained. A number of cases of glioma treated by radium have been collected by Stallard,[17] whose monograph contains valuable information concerning irradiation of other ocular conditions. The methods employed by him consisted in inserting radon seeds directly into the tumor through a scleral incision or applying them to the sclera directly over the tumor. Some encouraging results were reported.

Roentgen therapy has to its credit only the one definite case of Verhoeff [18] and that of di Marzio.[19] The diagnosis in Hilgartner's apparently favorable case was not made by sections of the first eye. Seefelder's case,[20] quoted by Kumer and Sallmann as successful, showed retrogression of the tumor following 30 H. E. D., but it recurred later. In Verhoeff's case a very small growth in the second eye of a 17-months' old child was treated by a "suberythema dose" repeated eight times during a year. Three years later only a small scar was visible and vision was about 20/30. No lens opacities developed in this case. I was able to examine this patient in Dr. Verhoeff's clinic, more than three years after treatment was begun. In a case reported by di Marzio a clinical cure was maintained for four years with preservation of useful vision by a 200 per cent skin erythema dose divided over several treatments. The first eye was enucleated. In another case a similar result was obtained but this has been under observation only five months.

Stock advises 180 per cent erythema dose, but this will vary greatly with the case. Cataract cannot in most cases be prevented, but this should not preclude the giving of effective dosage, and has not affected the ultimate result in the successful cases, after radium.

Although a number of melanosarcomas of the choroid, occurring in the only seeing eye, have been irradiated, in none of these, so far as the author knows, can a cure be claimed. R. Foster Moore [21] has recently reported an interesting case in which radon seeds were introduced into the tumor through a scleral incision, with resulting marked decrease in the size of the tumor and vision 3/60 after one year. It is much too soon to speak of a cure in this case, but this method gives, perhaps, the best chance of success in these otherwise hopeless cases.

Irradiation After Enucleation.—Irradiation of the orbit after enucleation for glioma or melanosarcoma has long been practiced by many ophthalmologists. Where careful examination of the enucleated eye, especially of frozen sections of the orbital end of the nerve in glioma, shows evidence of extension into the orbit or past the cut end of the nerve, irradiation is positively indicated, usually after evisceration of the remaining contents of the orbit. Even where such examination shows no extension, some believe it safest to irradiate as a precaution. The necessity of this is doubtful, however, especially in

melanosarcoma, since clinical experience has shown the rarity of local recurrence in this condition. Von Hippel, who has studied the subject carefully, believes it is sufficient to enucleate in these cases, and Wätzold, who formerly advised postoperative irradiation in every case, finds that recurrences fail to appear even in some cases showing evidence of extension, so that he now joins in von Hippel's opinion. The prevention of metastases by this means is doubtful, as is the prevention of glioma of the second eye, and since the scar tissue resulting from irradiation often makes the wearing of a prosthesis impossible, one hesitates to advise its use without more definite evidence of additional safety afforded. Where extension has occurred, or where one is in doubt, intensive x-ray or radium therapy should be given. Both methods have their advocates, and probably both methods should be used, radium needles or radon seeds being introduced into the orbit, and x-ray in addition. The x-ray will allow the dose of radium to be kept small enough to avoid bony necrosis. Where evisceration has been done, x-ray alone is to be preferred to avoid this complication.

Multiple Lymphomas.—A condition which is especially sensitive to either x-ray or radium therapy is that of multiple lymphomas of the orbit. These growths, which are usually symmetrical and form puffy swellings of all the lids, fairly melt away under the influence of either of these agents, and in case of doubt as to the diagnosis, a trial of irradiation should be made.

Grenz Rays.—A form of irradiation therapy which has been applied in ophthalmology is the use of the Grenz rays described by Bucky. These are rays of a length between the short ultraviolet and the long x-rays, and are absorbed almost entirely in the surface layers of the skin and mucous membranes, only 12 per cent penetrating deeper than 3 mm. Reports by Krasso [23] from the Meller Clinic in Vienna indicate marked beneficial effects in dendritic keratitis, blepharitis, rosacea keratitis, superficial corneal ulcers and sclerosing keratitis from this form of treatment. As compared with x-ray and radium, the method is very safe, and further reports on its use will be awaited with interest.

Pfeiffer [23a] has employed Grenz rays in a large number of ophthalmic diseases and observed encouraging results especially in superficial corneal ulcers and in sclerosing keratitis.

Massage

Massage is used chiefly in treating three conditions. In corneal ulcer the clearing of the corneal scar is probably hastened and promoted by gentle massage of the eyeball with a finger held over the closed lids (Fig. 11). Two per cent yellow oxide of mercury ointment is usually used in the conjunctival sac for lubrication and as a mild

irritant. The finger moves the lid back and forth over the cornea, such massage being kept up for five minutes three times a day. In glaucoma it is sometimes possible to keep the tension down to normal,

FIG. 11.—Massage of cornea to aid in clearing corneal scar.

FIG. 12.—Deep massage of eyeball to reduce intra-ocular tension.

especially after a filtering operation which does not produce quite enough effect, by massage. This forces fluid out of the eye, either through its normal channels, or through a small wound in the sclera made at operation, in which case it collects under the conjunctiva to

FIG. 13.—Massage of lids to empty meibomian glands.

form a small bleb. Such massage should be performed with the two forefingers which hold the eye between them beneath the lids, and are alternately pressed in and released so as slightly to indent the globe (Fig. 12). Just enough pressure should be used so that no pain

is caused. Pressure is made and released about thirty times and this is repeated two or three times a day.

In chronic infections of the meibomian glands, fluid accumulates in their ducts, and the result is recurrent chalazion or a diffuse thickening of the lids. Chalazia may often be prevented and the infection helped considerably by massage of the lids. This is done, as shown in Figure 13, by pressing with the two thumbnails on the skin side of the two lids which are held together and away from the globe. Pressure should include the whole lid border and should be continued until fluid ceases to come from the ducts of the glands at the lid border. Another method is to use a glass rod on the conjunctival side of the lid, which presses against a finger held on the skin side.

Muscle Exercises

In cases of squint of the nonparalytic type and of muscular imbalance, various types of exercise are used, most of them having the purpose of stimulating the defective fusion sense so that the eyes may be used together. In every case of squint the patient must first have a careful refraction, under a cycloplegic, and should wear his proper correction at all times. This alone, in about half of the cases of convergent squint with hyperopia, will correct the defect, and is the most important nonsurgical measure which we have against it. The use of glasses is *seldom effective in divergent squint.* If one eye remains constantly in the squinting position, an attempt should be made to improve its vision by covering the other eye for two hours a day with a bandage or close-fitting eye patch. Probably a considerably better way is to cover the better eye constantly for periods of several days, checking the vision at intervals and persisting in the occlusion as long as the vision improves. It is hard to do this where vision is very defective, as the child is then helpless and resists such treatment violently. Many cases show no improvement on such treatment and it is chiefly in very early cases, at the age of five to six, that an increase of vision is observed. A trial of such occlusion should be made when a case is seen early, no matter how defective the vision, though this may require considerable trouble and persistence on the part of both parents and physician. When a patient is first seen after the age of ten or twelve, the prospect of improvement is much less, and after the age of sixteen improvement is seldom observed. Where the difference in vision of the two eyes is not very great, the use of atropine in the good eye for varying periods, which paralyzes its accommodation and necessitates the use of the other eye for reading, may be of some benefit, but is certainly not so effective as occlusion.

Fusion Exercises.—Children past the age of six, or unusually cooperative younger children, may be suitable for the various types of fusion exercises. It is only in certain cases that benefit may be ex-

pected from such exercises. The squinting eye must have enough vision to see the objects used clearly, usually 20/200 or more, and it must be possible for the patient to see the images of both eyes at the same time. In many cases of squint the fusion faculty has become so defective that the image of the defective eye is suppressed, except when the other eye is closed.

Instruments.—By the use of prisms, with bases in for divergent squint, and out for convergent squint, the images may be brought close together, so that they may be seen at the same time. Eventually the patient may learn to fuse them into one image. This is facilitated by many special instruments. The cheiroscope of Maddox, by the use of mirrors, allows the images to be superimposed, no matter what the degree of squint, and small pictures or toys may be moved together on a board, or drawn, these procedures utilizing the movement of the objects to bring them into consciousness, and the simultaneous action of the hands and eyes to stimulate fusion.

The amblyoscope of Worth makes use of movable tubes through which pictures are seen and fused by moving the tubes. If the tube for the defective eye is held over a bright light, its picture is brought more sharply into consciousness. These two instruments are suitable for the more marked degrees of squint. In degrees less marked, and especially in cases of latent divergent strabismus, where one eye diverges only at certain times, the use of the ordinary stereoscope may be effective. Special charts are provided for this, such as the Wells and Guibor charts made in America, Hamblin's charts which are used a great deal in England, or Sattler's charts, published by Bergmann in Munich. The last are especially useful for small children, as they are so made as to give a marked impression of depth, and by changing the position of the cards, the relative position in space of certain parts of the picture is changed, so that the parent can tell when a child is correctly fusing the pictures. The Wells charts, besides using pictures which are partly defective, the defect in one being filled in by the image of the other, have a series of reading types in which the same principle is employed, smaller types being used as the exercises progress.

Muscle Imbalance Exercises.—Such stereoscopic exercises may be occasionally useful in cases of slight muscle imbalance, or weakness of convergence, with symptoms of eyestrain. These cases are usually treated by simpler methods than those used in squint, the simplest being converging exercises in which the point of a pencil or a dot on a card is slowly brought closer to the eyes until double vision occurs, and is then held off so that fusion is just possible. It should be possible gradually to bring the object nearer to the eyes without *diplopia*. Such exercises should be continued for three to five minutes two or three times a day.

Another simple method is that of bar-reading, in which a pencil, or a ruler 1 cm. wide, is held halfway between the eyes and the reading print in such a way that the letters are seen behind the ruler. This is then moved along before the eyes and the print is read behind the ruler. The exercise affords a constant stimulus to fusion.

INSTRUMENTS.—In muscle imbalance of various types, especially vertical imbalance, various instruments, such as the phorometer and kratometer, in which prisms of increasing strength are overcome by an effort of fusion, have been used. They are expensive and require frequent visits to the physician's office, and for this reason few patients will persist in their use long enough to obtain much benefit. The advantage of the simple stereoscope is that it may be given to the patient for use at home, and the same may be done with the amblyoscope.

In weakness of convergence, Gould's method of overcoming prisms with bases out may be used to advantage, prisms of increasing strength being loaned to the patient, who fixes an object at six inches and then backs off from it to a distance of twenty feet or until diplopia occurs. The same method can be carried out in other cases of imbalance, as described by Berens and Losey.

Evaluation.—The value of all these methods will depend greatly on the intelligence and co-operation of the patient, and it must be said that a great many cases will not be benefited. Patients with alternating squint, for example, often find it impossible to see both images at the same time, in spite of all our optical aids, and in such cases nothing but surgery will affect the squint. The same is true of marked degrees of squint with very defective vision. A great deal of judgment is necessary to avoid putting many of these patients to needless expenditure of time and money before advising necessary surgery. In the case of imbalance, the correction can be made simply by prisms worn constantly in the glasses.

RÉSUMÉ

After having reviewed the uses of various forms of physical therapy, the following résumé of common ocular conditions in which physical therapy is employed, with the form of treatment considered best for each condition, may help to clarify the material and facilitate its use in practice. To avoid repetition the reader is referred to the preceding text for the details of technic.

DISEASES OF THE LIDS

HORDEOLUM:

Moist heat, incision.

CHALAZION:

Incision and curettage.

Electrocoagulation; if on the lid border, 200 to 300 ma. for one second.

Xanthelasma:

Surgery is simplest in most cases.
Thermophore may be effective.
Radium is effective but requires care.

Blepharitis:

A trial of ointments and moist heat should be made.
In resistant cases, x-ray is most effective.

Trichiasis:

Electrocoagulation: 150 ma. for one second. If more than five or six lashes are affected, surgery is simpler.

Dermatitis:

X-ray is effective in small dosage.

Carcinoma:

Surgery for small growth not adherent to the bone.
X-ray where large areas of skin are involved.
Radium for growth at lid border or in the inner or outer angle, with adhesion to bone.

Nevus Flammeus, Hemangioma:

Radium, especially for capillary hemangioma.
Surgery for hemangioma supplied with large vessels.

Diseases of the Orbit

Cellulitis:

First 24 hours, cold packs. After this, moist heat and incision.
Medical diathermy, 200 to 400 ma. for five to ten minutes may be tried.

Carcinoma:

Radium needles or tubes of radon imbedded in growth.
Where orbit is to be eviscerated, electrocoagulation (surgical diathermy).

Sarcoma:

Electrocoagulation for evisceration of the orbit.

Lymphoma:

Radium in plaques over the lids. X-ray may also be used, but is not so effective.

Diseases of the Conjunctiva

Acute Conjunctivitis:

First 24 hours, cold packs; after this, moist or dry heat.

Chronic Meibomitis:

Massage of the lids.

Vernal Conjunctivitis:

Adrenalin locally and calcium systematically should be tried first. Where symptoms are not relieved, radium (see p. 26).

Neoplasms of the Bulbar Conjunctiva:

Surgery. Electrocoagulation may be useful if a weak current and a needle electrode are used. Radium is dangerous here.

DISEASES OF THE CORNEA

SERPENT ULCER:

Local applications, atropine, keratotomy. In early ulcer, phototherapy may be tried, using the carbon arc with uviol filter.

HERPETIC KERATITIS (DENDRITIC ULCER):

Phototherapy using carbon arc with uviol filter 8 to 10 minutes once a day. X-ray—30 per cent erythema dose (1 to 2 treatments).

EPITHELIAL DYSTROPHY:

Phototherapy may be tried.

DEGENERATED CORNEAL SCAR WITH ULCERATION:

Phototherapy as for herpetic keratitis.

SCLEROSING KERATITIS:

Phototherapy using carbon arc with uviol filter 10 minutes every two days. X-ray 15 to 20 per cent erythema dose, repeated after seven weeks, no more than three or four treatments being given.

CARCINOMA:

Beta irradiation may be of value.

Surgery is usually best, followed by careful use of electrocautery where the sclera or interior of the eye is involved. If this is refused, radium may be tried.

PHLYCTENULAR KERATITIS AND KERATOCONJUNCTIVITIS:

General treatment and atropine. The use of sun bath or general irradiation with the carbon arc or mercury vapor arc is of definite value in addition to other treatments.

CORNEAL SCARS:

Massage of the cornea and the use of dionin are probably of as much value as anything in helping to clear scars. The use of iontophoresis has been advised, but its value is questionable.

DISEASES OF THE IRIS AND CILIARY BODY

TUBERCULOUS IRITIS:

General treatment and atropine are most important. X-ray as described for sclerosing keratitis may be tried, but is not without danger of causing cataract. Hence it is contraindicated in the ordinary forms of iritis and other diseases of the iris and ciliary body. Beta irradiation may be of value.

DISEASES OF THE CHOROID:

No form of local physical therapy is probably effective. In tuberculous choroiditis the use of sun baths or generalized light baths with the carbon or mercury vapor arc may be of value.

DISEASES OF THE RETINA

GLIOMA RETINAE (RETINOCYSTOMA):

Enucleation of the first eye, followed by radium in the orbit if there is recurrence.

XANTHELASMA:

Surgery is simplest in most cases.
Thermophore may be effective.
Radium is effective but requires care.

BLEPHARITIS:

A trial of ointments and moist heat should be made.
In resistant cases, x-ray is most effective.

TRICHIASIS:

Electrocoagulation: 150 ma. for one second. If more than five or six lashes are affected, surgery is simpler.

DERMATITIS:

X-ray is effective in small dosage.

CARCINOMA:

Surgery for small growth not adherent to the bone.
X-ray where large areas of skin are involved.
Radium for growth at lid border or in the inner or outer angle, with adhesion to bone.

NEVUS FLAMMEUS, HEMANGIOMA:

Radium, especially for capillary hemangioma.
Surgery for hemangioma supplied with large vessels.

DISEASES OF THE ORBIT

CELLULITIS:

First 24 hours, cold packs. After this, moist heat and incision.
Medical diathermy, 200 to 400 ma. for five to ten minutes may be tried.

CARCINOMA:

Radium needles or tubes of radon imbedded in growth.
Where orbit is to be eviscerated, electrocoagulation (surgical diathermy).

SARCOMA:

Electrocoagulation for evisceration of the orbit.

LYMPHOMA:

Radium in plaques over the lids. X-ray may also be used, but is not so effective.

DISEASES OF THE CONJUNCTIVA

ACUTE CONJUNCTIVITIS:

First 24 hours, cold packs; after this, moist or dry heat.

CHRONIC MEIBOMITIS:

Massage of the lids.

VERNAL CONJUNCTIVITIS:

Adrenalin locally and calcium systematically should be tried first. Where symptoms are not relieved, radium (see p. 26).

NEOPLASMS OF THE BULBAR CONJUNCTIVA:

Surgery. Electrocoagulation may be useful if a weak current and a needle electrode are used. Radium is dangerous here.

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If the second eye is involved, a choice may be offered between enucleation and x-ray or radium (see pp. 29, 30).

Diseases of the Optic Nerve

Not amenable to physical therapy.

Intracranial Diseases

Pituitary Tumor:

If an adenoma is considered probable, roentgenotherapy may be tried, large doses being directed to the sellar region through the two temporal regions.

Where vision fails in spite of one or more treatments, no time should be lost in advising surgery.

Radium is used only where the tumor has eroded the floor of the sella, or after sellar decompression has been done.

Cerebral Tumors:

When tumor is inoperable or has been only partially removed, decompression should be performed if the vision is being damaged. Deep roentgenotherapy may then be tried (see p. 25).

Glaucoma:

Not amenable to physical therapy, except for the relief of pain by heat or cold and the use of massage for promoting filtration. X-ray and radium are contraindicated in the presence of glaucoma.

Cataract:

No form of physical therapy is indicated. The danger of producing cataract is one of the chief reasons for avoiding the use of radium and x-ray except where it is necessary and for the careful protection of the globe when this is possible.

Diseases of the Muscles

For the indications for muscle exercises, see p. 33.

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CHAPTER TWENTY-FOUR

PHYSICAL THERAPY IN OTOLARYNGOLOGY

JOSEPH C. BECK, M.D., AND M. REESE GUTTMAN. M.D.

INTRODUCTION

The extreme interest in physical therapy that is being manifested in general medicine and surgery is also encountered within the realm of the otolaryngologist. The enthusiasm displayed has apparently been boundless. Commercial interests have aided in the production of a teeming literature in which many unwarranted claims have helped popularize this somewhat spectacular form of therapy. Physical agents undoubtedly have a decided field of usefulness in the treatment of otolaryngologic disease, but in no sense are they a panacea. Many extravagant and irrational claims are found that often display an appalling lack of knowledge regarding the basic physics of the various energies employed and especially of their effects upon the human economy. Physical measures do not, as yet, constitute a system of therapeutics that can in any way supersede time-tried and scientifically evaluated measures in the treatment of disease and the alleviation of suffering. It follows that one must be extremely cautious of dogmatic assertions in such a young and as yet unproved branch of medical endeavor. The following reflects the views and beliefs of the writers as gathered from their experience with the various energies commonly employed.

OTITIS EXTERNA

Otitis externa exists in two well-recognized forms: otitis externa circumscripta or a *furunculosis* of the external auditory canal, and otitis externa diffusa which, as the name implies, is a nonlocalizing inflammation of the external auditory meatus. The offending organism most frequently seen in both types is the staphylococcus. The diffuse type is frequently seen following trauma, such as scratching of the ear, and also following an otorrhea due to middle ear suppuration. Not infrequently the extension of a furunculosis of the canal may also result in a diffuse external otitis. The diagnosis of these affections is easily made by inspecting the external auditory meatus, which will be found to be red and swollen. In the circumscribed form the inflammation will appear as a typical acuminate furuncle of which one or more may be present. The diffuse form will show as an inflammation that entirely

ular, pustular, or papular nature, or any combination of these. The otologist most often sees the more or less acute conditions that result from the continuous exposure of the skin to an irritating middle ear discharge. The diagnosis, as a rule, is not difficult to make, but frequently the etiologic factor may be hard to determine. The recent attention that is being given to allergy as a cause should be borne in mind.

Treatment.—In the treatment of eczema the indications are to remove the cause and protect the involved area from further irritation. The more chronic and indolent lesions require the use of stimulating agents, in which case *physical therapy* in the form of *x-ray* or *ultraviolet irradiation* may be of benefit. In the treatment of eczema following an otorrhea it is decidedly important not to permit the discharge to collect about the meatus. The discharge should be gently wiped away with a cotton-tipped applicator or toothpick as quickly as it forms. The patient should be warned of the dangers of wounding the canal during the use of these applicators. In the more chronic types of eczema, systemic measures for the regulation of the diet, and avoidance of exposure to offending proteins in the allergic types, are of importance. In those cases in which fissuring and oozing are pronounced, calamine lotion or the various dusting powders may be employed. Ointments containing zinc oxide or crude coal tar are of especial benefit.

Physical therapy may be of benefit in the subacute and chronic forms. *Ultraviolet irradiation*, given on alternate days, may be effective. The first exposure should be for one minute at a distance of ten to fifteen inches and the dose should be increased by one-half minute until a maximum of five minutes is being used. In the more stubborn types that do not respond to local medication and *ultraviolet irradiation*, benefit will sometimes be obtained by *x-ray therapy*. The *x-rays* should be applied in doses of one-fourth skin unit of the unfiltered ray at weekly intervals. It is important when using the various types of irradiation to cleanse the skin surface thoroughly and dispense with the use of any of the skin ointments or medications. It is also well to protect the area about the ear by means of cardboard properly cut and placed when using *ultraviolet irradiation*, or by means of heavy lead foil when using the *x-rays*.

Erysipelas of Auricle

The practicing otologists see erysipelas of the auricle most frequently as a complication following mastoid surgery. It is also observed in the aged in conjunction with recurrent attacks about the head and face. The diagnosis as a rule is not difficult to make. The initial chill followed by a rise in temperature and the appearance several hours later of the characteristic elevated redness with its line

occludes the meatus. In both forms pain on traction of the auricle is present and is a pathognomonic sign that serves to distinguish these inflammatory conditions from an acute otitis media.

Treatment.—The treatment should be as conservative as possible. Physical therapy in the form of *infra-red irradiation* is the treatment *par excellence*. A twenty-minute session at least three times a day is advisable. In addition one may employ *hot moist applications*, using a saturated solution of magnesium sulphate or boric acid. Aspirin, pyramidon, or even codeine may be administered for the pain. One should abstain from any irrigation or manipulation of the canal. If resolution or spontaneous rupture does not occur, the center of suppuration may be nicked, but not deeply cut, with a fine bistoury, provided, however, that localization and liquefaction have occurred. After the incision one should avoid squeezing, mopping, manipulation. The use of the *infra-red irradiation* and the *moist compresses* should be continued after the incision. It should be emphasized that any trauma, including extensive incision, before localization has occurred has been followed by grave complications and even death.

Two relatively new measures have been advocated recently for both the treatment and the prevention of recurrent otitis externa. One is the use of Besredka's antivirus instilled into the ear several times a day. The other is the application of *tin ionization* to the external auditory canal. The technic employed is similar to that used in chronic otorrhea. An insulated ear speculum such as is used for zinc ionization for the treatment of middle ear discharge is placed into the canal and then a solution of stannoxyl, which is a mixture of tin and tin oxide, is instilled into the speculum and the canal. The positive electrode is attached to the wire in the center of the speculum and the negative electrode is held in the hand. The current should be gradually turned on until three to five milliamperes are in use. This is permitted to act for ten minutes and is repeated on three successive days. Immediate relief from pain is said to occur.

Recurrences are not at all infrequent. They may be prevented to some extent by warning the patient strictly to avoid the use of matches or hairpins within the canal. During the quiescent interval one may employ *x-ray irradiation* to the external canal. Instead of the *x-ray*, an erythema dose of *ultraviolet irradiation* applied by means of a *quartz applicator* may be tried. The use of Besredka's antivirus is also said to prevent recurrence.

Eczema of Auricle

Eczema of the auricle may exist as either an acute or a chronic inflammatory condition of the skin. It is frequently accompanied by severe itching and sometimes is associated with a seborrheic dermatitis of the scalp or face. The lesion may be of an erythematous, vesic-

insist on early and radical surgical removal by *electrosurgical methods* and then the use of *irradiation* as an adjunct. It is well to excise the auricle wide of the growth with the tissue-cutting current and then to use the coagulating current upon the base. The *x-rays* or *radium* used preoperatively or postoperatively may add to one's security in establishing a cure.

Otomycosis

Otomycosis or otitis externa parasitica is a dermatitis of the external auditory meatus due to a fungus infection, the most frequent offenders being either the *Aspergillus niger* or *glaucus*. It is manifested as a marked irritation of the canal frequently associated with severe itching and sometimes with attacks of pain radiating into the face. Upon inspection, the auditory meatus will be found to be red and covered with a peculiar moist speckled substance which has the appearance of wet blotting paper. The coating may be spotted with small black or brownish areas the size of a pinhead. The diagnosis is definitely established by culturing the material found in the canal upon Sabourraud's media, when a characteristic growth will be obtained.

Treatment.—The treatment consists of the use of exfoliating agents in the canal. A 10 per cent solution of salicylic acid in alcohol may be used twice a day for the period of a week. Physical measures may also be employed, especially in the more resistant cases and in those in which the affection tends to recur. *Ultraviolet irradiation* applied to the external auditory canal by an appropriate quartz aural applicator may be of benefit.

Pruritus of External Auditory Canal

This exasperating condition is not infrequently present as a secondary manifestation of some inflammatory condition within the external auditory canal. It may, however, be unaccompanied by any discernible pathology in the meatus. In these cases especially it is a most refractory condition. The patients who are so unfortunate as to be troubled with this affliction return at frequent intervals suffering from an acute inflammatory otitis externa due to traumatizing the canal with a match, hairpin, or similar object. In a few instances the pruritus disappears following the removal of an impacted molar.

Treatment.—The treatment of the idiopathic type is frequently unsatisfactory. Itching secondary to an otorrhea or otomycosis is quickly relieved by proper attention to the primary condition. In the idiopathic types in which no pathology may be seen in the canal, it is well to perform a thorough search of the trigeminal area for contact or pressure points that might cause pruritus through reflex action. Locally calamine lotion containing phenol may be instilled into the

of demarcation is a picture that cannot easily be mistaken for anything else.

Treatment.—In the treatment the early use of anti-erysipelas serum is advocated. Locally one may employ *ice compresses* of a saturated solution of magnesium sulphate. In addition the edge of the spreading lesion should be painted with contractile collodion. These measures may effectively prevent any progression. Recent reports indicate that physical therapy may be of benefit in erysipelas. *Ultraviolet irradiation* has been advocated and it has been recommended that one and one-half erythema dose be applied. With a good lamp this dosage may be effected by a 12 to 15 minute exposure at a distance of 100 cm.

X-ray irradiation has also been utilized with apparently some benefit. The irradiation should be administered in one exposure, the amount being a mild erythema dose, using a filter of two millimeters of aluminum. According to published reports, a marked diminution in the symptoms may be expected within 24 hours by the use of either of these agents.

Perichondritis, Chondritis, and Suppuration of Auricle

These conditions most frequently follow trauma to the auricle, or an infection in a hematoma of the auricle. They are also seen as complications of severe external otitis in people that are below par physically or afflicted with some debilitating systemic disease, such as diabetes. The diagnosis is not at all difficult. Systemic conditions must be appropriately dealt with. Locally *infra-red irradiation* and *warm moist applications* as described for inflammations of the external auditory meatus are advocated. When suppuration has occurred, incision and evacuation of the pus are necessary. It is well to warn the patient in advance of the possible shrinkage and deformity of the auricle that may follow.

Malignant Disease of Auricle

Carcinoma and sarcoma are the most frequent malignant tumors of the auricle that are encountered in practice. The diagnosis is definitely established by biopsy of a portion of the growth. In the treatment, early diagnosis when the lesion is small and well localized and without any metastases is essential for a cure. *Radium* is said to be of value in these conditions. If the lesion is a basal cell carcinoma and is more or less superficial, and if the underlying cartilage has not been involved, the use of about 75 to 150 mg. hr. of radium, with a 1-mm. platinum and 4-mm. rubber screen, has been advocated. This *irradiation* may have to be repeated at intervals of one to three months. However, we have not been impressed with the results obtained by *irradiation* of other types of malignant growths. It has been our practice to

insist on early and radical surgical removal by *electrosurgical methods* and then the use of *irradiation* as an adjunct. It is well to excise the auricle wide of the growth with the tissue-cutting current and then to use the coagulating current upon the base. The *x-rays* or *radium* used preoperatively or postoperatively may add to one's security in establishing a cure.

Otomycosis

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meatus several times a day. Physical therapy in the form of *ultraviolet irradiation* has been of help. A short irradiation, applied by means of a quartz anral applicator, repeated upon three or four successive days, may help to alleviate the patient's distress. The x-ray as described for chronic eczema may also be of help.

Herpes Oticus

Herpes oticus, otitis externa herpetica, or bullous myringitis is a condition of the external auditory canal and tympanic membrane that is characterized by an eruption of more or less hemorrhagic bullae that are, as a rule, surrounded by an inflammatory base. They are most frequently seen during an influenza epidemic and are supposedly due to an infection of the geniculate ganglion with a filtrable virus. The

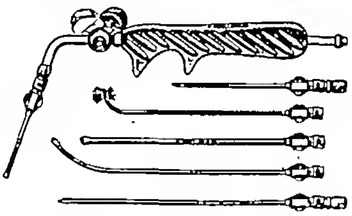

Fig. 1.—Suction handle and tips for the ear, nose, and sinuses.

characteristic picture of the bullae and the normal hearing serve to differentiate this condition from acute otitis media.

Treatment.—In the treatment the local use of phenol in glycerin or the topical application of metacresylacetate, aided by *hot compresses* of a saturated solution of magnesium sulphate or boric acid, is advised. The bullae should not be opened. *Physical therapy* in the form of *infra-red irradiation* is helpful in relieving the pain. The exposure should last for at least 20 min. and be repeated several times a day.

Otitis Media

Suppuration of the middle ear is such a common condition that little will be mentioned regarding its causation, symptomatology, or diagnosis. In the treatment of the early stages the use of *hot applications* and *infra-red irradiation* may lead to relief of pain and regression in a limited number of cases. In addition, drainage of the middle

ear via the eustachian tube should be promoted by the use of ephedrine solution within the nose. If the symptoms persist and bulging ensues, a myringotomy should be performed. After myringotomy the secretion should be aspirated from the canal by the use of capillary suction (Fig. 1). The *hot application* and *infra-red therapy* should be continued, and in addition, antiseptic drops may be instilled into the meatus. The use of *diathermy* is contraindicated before the rupture of the drum, and after incision it is of little benefit. Mass suction to the auditory canal is also to be deprecated as it may cause congestion of the parts and, not rarely, prolapse of the tympanic mucosa through the perforation.

Acute Mastoiditis

This condition presents a picture of an acute middle ear infection that has persisted for several weeks and is associated with persistent pain, mastoid tenderness, temperature, and loss of hearing. X-ray of the affected mastoid may show cloudiness or destruction of the mastoid cell. In the treatment the use of *moist applications, radiant heat,* and *capillary suction* as advocated for acute otitis media are recommended. If the symptoms show no tendency to ameliorate, or if signs of complications appear, surgery of the mastoid must be considered. Medical *diathermy* is mentioned only to be condemned in such conditions.

Following mastoid surgery, slow healing of the wound is sometimes seen. There is generally associated some systemic condition that must be corrected. *Ultraviolet irradiation* to the open wound has been advocated with the idea of stimulating the granulation formation and shortening the time for healing.

Chronic Otitis Media

This condition is characterized by a chronic infectious process located within the tympanum or its adnexa. Two characteristics are of extreme interest to the physical therapist, namely, otorrhea and hardness of hearing, and these will be treated as separate subjects.

Chronic Otorrhea

Chronic otorrhea should be considered as a manifestation of an infectious process within the tympanomastoid and the eustachian tube. The infectious process may be restricted to the mucous membrane or may affect the underlying bone. Certain complicating pathology may be the cause of the persistence of an otorrhea. Systemic diseases, such as tuberculosis and syphilis, may be the offending factors. Locally the otorrhea may be aggravated or even caused by a pathologic condition in the nasal mucosa, the nasal sinuses, or the adenoid mass. In addition, local causes within the ear itself must be

considered, such as granulations, polypi, caries, cholesteatomas, and even malignancies. An otorrhea presupposes a perforation within the drumhead. As a rule a central perforation, namely, one that does not touch the periphery, has a tendency to heal, while a marginal perforation, that is, one that involves the margin, has a tendency towards chronicity and the formation of cholesteatoma. The etiologic organisms are also important factors in the production and maintenance of an aural discharge. Otorrhea following scarlatina, measles, or tuberculosis is notoriously difficult to control.

Treatment.—In the treatment of otorrhea appropriate attention to such complicating pathology as may be located in the adenoids, sinuses, or nasal mucosa is of importance. Systemic disease, such as syphilis, diabetes, and tuberculosis, must also be properly dealt with. The use of generalized *ultraviolet irradiation* or *natural heliotherapy* is an adjunct that may be utilized with some benefit, especially in children that are below par physically.

The local treatment consists in the strict avoidance of water within the ear and the use in its stead of local capillary suction (Fig. 1) for removing the secretions from the canal and tympanic cavity. Aqueous irrigations are best eliminated except under certain circumstances. Should irrigation be necessary, it is far better to utilize weak solutions of alcohol. For home use one might prescribe antiseptic drops containing alcohol or ether in addition to phenol or tincture of iodine. These drops may aid both in dehydration and antisepsis.

Granulations and polypi should receive proper care. Physical methods have been widely advocated. As a rule, we have seen little or no benefit follow the use of local *ultraviolet irradiation* or *medical diathermy*, in spite of the enormous amount of literature dealing with the use of these agents in this condition. The physical measure of choice in the treatment of a chronic otorrhea is the use of *zinc ionization*. However, its use is indicated only in those certain simple types of uncomplicated otorrhea with relatively large central perforations. Cases of otorrhea due to chronic mastoiditis and cholesteatoma and cases with tiny central or peripheral perforations have been benefited in only a very small percentage of the cases, if at all. These conditions, therefore, contraindicate its use. Its use is also unsuccessful if no attention is paid to disturbances in the nasal sinuses or nasopharynx.

Technic.—Prior to the use of *zinc ionization* the ear should be cleansed of any of its contained secretions by wiping or, better yet, by the use of capillary suction. In *zinc ionization* the patient must lie with the affected ear uppermost and a solution of zinc sulphate, one grain to the ounce, should be used to irrigate the ear. An appropriate aural applicator (Fig. 2) is then placed in the ear and the positive pole of the galvanic apparatus is connected to the zinc wire within the applicator. The negative pole is connected to a moist sponge

electrode or piece of lead foil that may be either held in the hand or firmly placed anywhere on the body. The current is gradually turned on until two to four milliamperes are being utilized. One should be guided by the tolerance of the patient and one should be ready to decrease the current immediately upon the appearance of a labyrinthian irritation. *The current should be permitted to flow from 10 to 15 min.* In many cases one such treatment may be sufficient to effect a dry ear. In other cases two to five séances may be necessary. In the intervals one may insufflate anhydrous boric powder or one of the iodine boric powder combinations.

FIG. 1.—Aural electrode and galvanic apparatus for ionization.

Deafness

Before undertaking the treatment of deafness in a patient it is absolutely essential to determine the type and, if possible, the cause of the auditory impairment. Deafness due to obstruction of the external auditory canal by a foreign body, impacted cerumen, or an inflammatory stenosis requires attention to the causative factor. Hearing difficulty may also be due to inflammatory processes within the tympanomastoid and the associated eustachian tube and nasopharynx. The nature of the processes may be varied. The eustachian tube may be blocked by an adenoid vegetation or by stenosis within its lumen. Such conditions require appropriate care. The middle ear may be the seat of a serous or purulent exudate or of a postinflammatory adhesive fibrosis. The fluid content must be evacuated, especially when suppuration is present.

Treatment.—DIATHERMY.—Medical diathermy should never be used in case of an acute suppurative otitis media unless free drainage is present, and even under these circumstances its exact value is questioned. We have been unable to note any beneficial influence upon the middle ear suppuration after incision of the drum with the use of *medical diathermy*.

It was thought that *diathermy* might ameliorate serous accumulations within the middle ear. In a small series of cases subjected to this form of therapy, no demonstrable improvement could be noticed. However, rapid increase of the hearing took place upon paracentesis that was followed by inflation. One would, therefore, hesitate to recommend the employment of *medical diathermy* for a serous otitis media.

Chronic adhesive otitis media is one of the prolific causes of hardness of hearing. *Diathermy* has been advocated in this form of hearing de-

FIG. 3.—Active electrode in medical diathermy of the ear.

crease on the assumption that it could cause the absorption of the effusions and softening of the intratympanic exudate and fibrosis. However, the critical observer is somewhat skeptical of the ability of the relatively small amount of heat caused by *medical diathermy* to produce such remarkable effects upon scar tissue. In actual practice such skepticism has been substantiated. In spite of many enthusiastic claims to the contrary, we have proved, to our satisfaction at least, that *diathermy* has caused little if any benefit in chronic otitis media. In a certain percentage of the cases that receive little benefit by this physical measure, some increase in the hearing was obtained by inflation and those cases that showed no response to inflation did not, as a rule, show any benefit after the use of *diathermy*.

Otosclerosis was not influenced for the better. Not a single case subjected to *diathermy* showed any change in the hearing. In fact,

not a few of the patients complained of some increase in the intensity of the accompanying tinnitus.

Labyrinthian deafness following inflammation or fracture was in no way influenced by *diathermy*. It is inconceivable that any amount of heat could cause regeneration of the destroyed neuro-epithelium or absorption of the postinflammatory fibrosis.

For those who may wish to try *medical diathermy* for deafness or tinnitus, the following technic is employed: The active electrode is placed over the mastoid region of the affected ear (Fig. 3) and the larger indifferent electrode over the opposite cheek (Fig. 4). Placing the electrodes in these positions causes the so-called *diathermy* beam to traverse the tympanum, the labyrinth, and the eustachian tube. Three

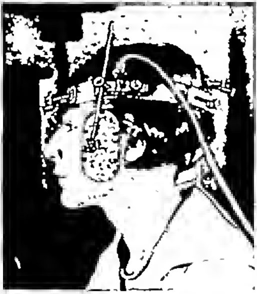

FIG. 4.—Indifferent electrode in medical diathermy of the ear.

to four treatments a week, each one lasting from 20 to 30 min., have been advocated. The strength of the current should be gradually increased, and it is only rarely necessary to utilize more than 400 or 500 ma.

One may encounter disagreeable effects due to labyrinthian irritation which, when present, should cause an immediate reduction in the amount of the current used. It is well to check the effect of the treatment by frequent functional tests and to discontinue the *diathermy* if no benefit is manifested. Many patients suffering from progressive deafness will believe that they hear better after any type of treatment, even though functional testing may show no improvement.

X-RAY.—*X-rays* have been employed in two ways in the treatment of deafness. In one the use of the so-called diminutive dose to stimu-

late the pituitary, pineal, thyroid, parathyroid, and thymus glands has been advocated. The technic as described consisted of a cross fire via the back of the head, through the open mouth, and also through the sides of the head. The gratifying results claimed could not be substantiated by most people.

The second method consisted in the use of a so-called sclerolytic dose of *x-ray* to cause a reduction in the lymphoid structures situated about the postnasal space and the eustachian tubes. This apparently more rational form of therapy may be of some aid in the restoration of hearing if the deafness is due to eustachian tube blockage by lymphoid

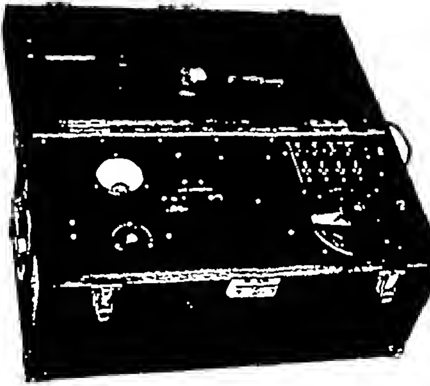

Fig. 5.—Showing working parts of the No. 1-A audiometer. (Courtesy of the Western Electric Co.)

tissue. However, it is oot as yet an accepted procedure and has been discontinued by many. For those that may wish to try it the technic as advocated will be described.

The patient should lie oo a table aod the entire head (except a small area about one inch in diameter about the external auditory meatus) is protected hy heavy lead foil. The exposed area is subjected to *x-ray irradiation* with the following factors: 5 ma. at 8 kv. (root means square) through a 1-mm. aluminum filter with the tube at a distance of 15 in. for 4½ min. The other side is then irradiated in the same manner.

Method of Testing Hearing.—AUDIOMETER.—This newer method of testing the hearing has been elaborated during the last several years. There are several types of audiometers, but the most popular is the one developed by Harvey Fletcher (Fig. 5). It consists of a thermo-ionic tube circuit in which the tube is placed into oscillation. By varying the electrical constants of the circuit, one may make the emitted tone assume various pitches which range, in this certain type of audiometer, from 64 double vibrations to 8,192 double vibrations. A suitable mechanism so calibrated as to record the hearing deficiency in a loss of sensation units is incorporated into the circuit for varying the intensity of the tone. In using the instrument the hearing for each ear is tested separately. The patient places the receiver against his ear and the switches are set in contact so that the various tones may be produced. The intensity of these tones is gradually reduced until the patient can barely perceive them and the loss in sensation units is read directly from the instrument and charted upon a graph (Figs. 6, 7, 8, 9). In general, certain graphs may be more or less characteristic. A conduction type of deafness will show a graph in which there is a relatively large hearing loss in the lower tones while the upper tones may be uninvolved. Nerve deafness will show a hearing loss in the upper tones while otosclerosis may show a hearing loss that is most pronounced in both the upper and lower registers.

TINNITUS AURIUM

This decidedly harassing condition is one with which the otologist is frequently confronted. It should be considered as a symptom and not as a definite clinical entity. It may be due to systemic disturbances, such as variations in the blood pressure, blood dyscrasias, arteriosclerosis, syphilis, and other organic diseases. Local conditions about the ear may also be associated with tinnitus. Impacted cerumen or foreign bodies, especially insects, may give rise to this disagreeable symptom. Suppurative processes in the middle ear and their adhesive sequelae may also cause tinnitus. Otosclerosis and labyrinthian disturbances are attended by tinnitus in most cases, and certain intracranial conditions, such as acoustical tumors, may also be the cause of this symptom. It follows that the treatment must depend first upon an accurate diagnosis as to the cause of this condition and its proper elimination. *Diathermy* is a physical measure that has been repeatedly advocated. Unfortunately, in the authors' hands it has been attended with but little success. In fact, in not a few cases the tinnitus was aggravated by the treatment. The technic by which the *diathermy* is applied is similar to that described under middle ear and mastoid disease; that is, the electrodes are used over the mastoid region of the affected ear and the opposite cheek respectively. Twenty-minute treatments should be repeated at appropriate intervals. In those cases of tinnitus associated with hypertension, one may try autocondensation.

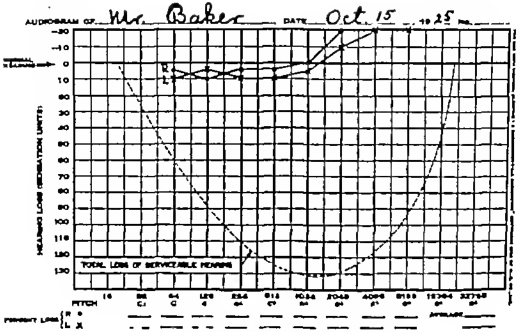

Fig. 6.—Audiogram showing normal hearing.

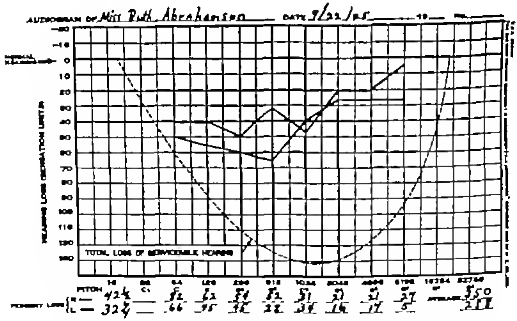

Fig. 7.—Audiogram showing bilateral conduction deafness in a patient who had had a bilateral radical mastoid operation.

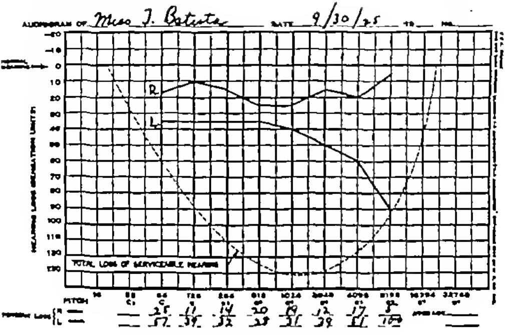

Fig. 8.—Audiogram showing nerve deafness in left ear.

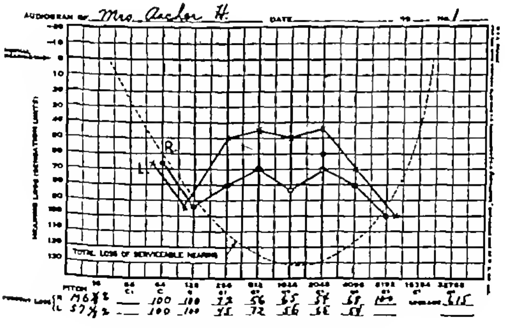

Fig. 9.—Audiogram showing graph of otosclerosis.

Tests of Labyrinthian Function.—CALORIC TECHNIC.—The labyrinth may be tested in the classic manner by douching the ear with either hot or cold water. It is customary to use cold water at a temperature of 20° C. (68° F.), and to note the time required for the production of a nystagmus and the associated symptoms of vertigo, nausea, pallor, and sweat. Selective stimulation may be obtained by placing the head in a proper position. With the head bent 120° forward or 60° backward, the horizontal canal on the irrigated side will be affected. With the head bent 30° forward, the vertical canals will be affected. In the presence of tympanic suppuration or a suspected labyrinthian fistula, the irrigation would, of course, be contraindicated. In such cases one may employ the galvanic current as a source of stimulation.

GALVANIC TECHNIC.—The patient must be seated and must look at a distant object. The anode from a galvanic apparatus is held firmly in the hand and the cathode is applied to the tragus. The current should then be gradually turned on. The normal labyrinth will respond to a current of from four to six milliamperes. In case of hyperesthesia of the labyrinth, the response may occur with as little as one milliampere. In hypofunction of the labyrinth, a current strength of more than six milliamperes may be required.

RHINOPHYMA

Rhinophyma presents such a characteristic picture that no description will be attempted. If the lesion is small and well localized, it may be entirely destroyed by *electrocoagulation*. The larger and more extensive growths should be removed by careful shaving with a razor, such as is used for the Thiersch graft, until the normal contour of the nose is obtained. The profuse bleeding that follows may be controlled by the use of a fine *electrocoagulation* current over the bleeding surface or by the use of hot packs.

FURUNCLE OF NOSE

This condition most frequently follows the removal of one of the vibrissae from the vestibule of the nose. There results a folliculitis about the hair follicle which tends to remain localized. However, if the vibrissae are subjected to trauma, such as deep incision or squeezing, grave complications may occur. The venous channels about the site of the furuncle communicate directly with the veins of the orbit via the angular vein and an extension of a thrombophlebitis upwards along the angularis following the manipulation of a furuncle may produce a cavernous sinus thrombosis with its fatal outcome.

Treatment.—The treatment consists of the strict avoidance of any local manipulation. Incision is to be condemned. Local applications

of *hot compresses*, using a saturated solution of magnesium sulphate or boric acid, are recommended. *Infra-red irradiations* for 20 min. several times a day are helpful in promoting localization and relieving the pain. It is far better to permit the furuncle to rupture spontaneously. If symptoms of high fever associated with toxemia appear, one must consider ligature of the angular vein high up alongside of the nose in order to ward off possible extension of a thrombophlebitis. *X-ray treatment similar to that employed* for *carbuncle may also* be utilized.

Epistaxis

Nasal bleeding may be due to a variety of causes, both local and systemic. Hypertension, blood dyscrasia, scurvy, sclerosis of the liver, and typhoid fever are a few of the general etiologic factors. Locally epistaxis may be due to nasal ulceration or malignancy. It is very frequently due to the pernicious habit of nose-picking. There soon results an abrasion of the septal mucosa with subsequent bleeding. By far the greatest number of cases of epistaxis is caused by a telangiectasia in the region of the anterior lower portion of the nasal septum, which is known as Little's or Kiesselbach's area. This bleeding may, as a rule, be controlled by the topical application of *chromic acid bead* or the use of the *galvanocautery*. The bleeding site should be anesthetized with a 10 per cent solution of cocaine and the area gently touched. When using the *galvanocautery* the point should never be heated to a wb'te glow as in such cases the cautery tip will cut rather than cauterize.

Radium has also been advocated. It is used to produce an obliterating fibrosis of the telangiectatic vessels. The dosage that has been described is 75 to 100 mg. hr. of the radium element. After proper cocainization, a 25-mg. capsule screened witb 0.5 mm. of platinum, brass, and gutta-percha is placed beside the lesion and permitted to act for 3 or 4 hrs. If necessary, a similar application may be repeated from 4 to 6 weeks later. The exact value of this procedure has not as yet heen definitely determined. *Electrocoagulation* has been advocated in this region for the purpose of destroying these vessels. Extreme caution is advisable in the use of this powerful agent since not a few cases of septal perforation have followed its use. The *galvanocautery* is recommended in preference to *electrocoagulation*.

Acute Rhinosinusitis

This condition is characterized by acute inflammation of the mucous membrane of the nose. In practically every rhinitis or "cold" the sinuses are involved at the same time. The symptoms are well known. The chilly sensation, malaise, nasal blockage and discharge, together with a more or less severe headache, are the usual complaints. Upon inspection the turbinals are swollen and edematous, preventing a good

inspection of the deeper parts. In addition the mucopurulent discharge is present. An x-ray taken at this time may show a slight haziness or even distinct cloudiness of the paranasal sinuses.

Treatment.—In the treatment, systemic measures may be of decided use. A hot bath followed by a glass of hot lemonade and the exhibition of empirin compound are measures that may promote free sudoresis. Liquids should be forced, and measures should be taken to evacuate the bowels. Locally the nose should be treated by instilling a three per cent aqueous solution of ephedrine by means of a dropper or an atomizer. The resultant shrinkage of the nasal mucosa will promote ventilation and drainage of the sinuses. Ephedrine is best used at four-hour intervals. Between treatments, mild silver antiseptics, such as

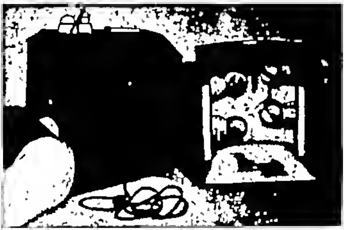

FIG. 10.—Illustration showing Bruenning's electric head cabinet in use.

argyrol or neosilvol, may be dropped into the nose. Physical measures may be of aid. Capillary suction, for which a nasal suction tip is used (Fig. 1), is frequently of aid in removing the secretions from the nose. *Infra-red irradiations* over the face and sinus areas may also be of help. Twenty-minute exposures several times a day are advocated. During the exposure the eye should be covered with moistened gauze. One may also employ the *Bruenning electric head cabinet* (Fig. 10) for a similar purpose. The cabinet is constructed so as to fit about the head. On the inside are electric light bulbs which are the source of the heat. Results obtained by the use of the *Bruenning cabinet* are in no way superior to those obtained with the customary type of therapeutic heat lamp. *Diathermy*, while advocated, has not proved of much benefit in these conditions.

In children general body irradiation with *ultraviolet rays* is said to prevent recurrent attacks of rhinitis.

Chronic Hypertrophic Rhinitis

This condition is the familiar "catarrh" that the rhinologist is frequently confronted with. There exists a state of chronic turgescence or hypertrophy of the nasal mucosa, especially about the inferior turbinate. Repeated colds and dietary deficiency may have something to do with its production. Sinus pathology is frequently associated with it and may be the basic cause. The most pronounced symptoms manifested are impairment of nasal respiration and nasal discharge.

Treatment.—In the treatment of this condition any systemic disease or dietary deficiency should receive adequate consideration. The paranasal sinuses require investigation and treatment if at fault. Local measures applied to the nose, such as shrinkage with ephedrine and the use of the Dowling argyrol packs, may be of service.

Physical measures have also been advocated. *Medical diathermy* has been of little or no benefit, in our hands, at least. When a large

Fig. 11.—Tip for galvanocautery of the inferior turbinate.

bulbous inferior turbinate is the cause of the difficulty in respiration, it may be reduced in some instances by the use of the *galvanocautery.* A special nasal cautery tip (Fig. 11) is heated to a bright red and the mucosa of the turbinal seared after proper anesthesia has been effected. It is well to place two parallel sears along the entire length of the medial aspect of the turbinate, as well as one under its inferior aspect. After the cautery one might take the precaution to insert a piece of wax paper sterilized by immersion in bichloride or alcohol between the turbinate and the septum in order to prevent the formation of a synechia.

Intramural Electrocoagulation of Turbinates.—One of the authors has recently elaborated a method of *electrocoagulation* of the turbinal to be used in place of the cautery. The cautery has the disadvantage of being followed by a marked reaction and by the formation of crusts and sometimes of adhesions. Secondary hemorrhage is also not unknown. The method advocated has none of these disadvantages. A special needle electrode (Fig. 12), made by insulating a long surgical needle with a special bakelite compound within a millimeter of its point, is used. The needle electrode is fitted into one of the customary handles and connected to a diathermy machine. In use the needle is inserted into the head of the inferior turbinate and carried along the medial aspect of the bone towards the posterior extremity

of the turbinal (Fig. 13); then, by means of a foot switch, the current is turned on and the needle is slowly withdrawn. One may also interrupt the current at varying intervals. Two such coagulations are placed within the turbinal along its medial aspect, and one coagulation, along its inferior aspect (Fig. 14). Before the needle is used on the patient, the strength of the current is adjusted by trying it on a piece of beef. The proper current is found when one is able to produce an area of coagulation of about one or two millimeters around the needle point.

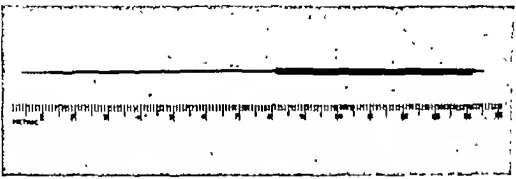

FIG. 12.—Guttman electrode for intramural electrocoagulation of the inferior turbinate.

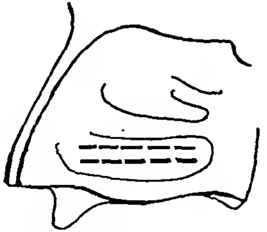

FIG. 13.—Course of the turbinal electrode within the body of the inferior turbinate.

While many gratifying results have been obtained, the use of this method has not been observed sufficiently long for its value to be definitely ascertained. The danger of infection within the cavernous tissue or of osteomyelitis of the turbinal bone, due to destruction of the periosteum, has not been lost sight of, but as yet has not occurred. Theoretically any infection introduced with the needle should have been destroyed by the coagulation and further, the amount of periosteum that may be involved in the coagulation is only about a

millimeter in extent so that the slight loss of the nourishing membrane may not be of practical importance.

Zinc Ionization.—*Zinc ionization* has also been advocated as a measure that may decrease the discharge and relieve obstruction. Its exact value has not as yet been definitely established, but it is well worth a trial. The nose is first cleansed by capillary suction and the entire nasal chamber is packed with strips of gauze impregnated with a one per cent solution of zinc sulphate. A flexible wire is fixed into the packing and connected to the positive terminal of a galvanic apparatus. The negative terminal is suitably applied to the patient's arm, the

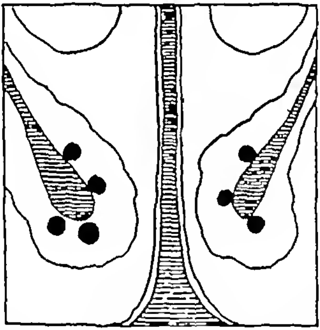

Fig. 14—Cross section of inferior turbinates, showing the location of the several streaks of electrocoagulation in relation to the periosteum of the turbinate.

current is then gradually turned on until about 10 ma. are being utilized, and this is permitted to act from 10 to 15 min. while the current is slowly decreased. The pack is then removed. The mucosa will be found to have a shrunken, grayish appearance. Improvement is said to manifest itself within a week, although the symptoms sometimes may be aggravated for a day or two. In obstinate cases the procedure should be repeated at weekly intervals.

Atrophic Rhinitis

The clinical picture of *fetor ex nasi*, associated with the intranasal accumulation of greenish crusts and the "roomy" appearance of the

nasal fossa, is so characteristic that no further description will be attempted.

The cocci-bacillus of Prez and Abel is supposedly the offending organism and is found in conjunction with many other organisms, especially the pseudodiphtheria bacillus.

In the treatment measures that aid in the removal of crusts are indicated. Various stimulating medicaments may be applied locally. Vaccine therapy has not been successful. Operative measures to decrease the roominess of the nose, such as the submucous implantation of ivory or various other procedures for moving the lateral nasal wall towards the midline, have been advocated with excellent results in many cases. This is especially true in ivory implants. Physical methods have also been utilized. The use of intranasal quartz has been attended with but little success in the authors' hands. More promising is the use of radium. Two 50-mg. tubes of radium screened with 0.2 mm. of platinum and enclosed in a 1-mm. brass tube are inserted against the lateral wall of the nose for one hour on each side. Within a week an acute reaction will occur which subsides within two or three weeks with a decrease in the fetor and scab formation. Three to five such treatments may be given at appropriate intervals. Sufficient experience, however, has not been had with this method, so that further trial is necessary before its worth can be definitely evaluated.

Intumescence of Inferior Turbinal

This very common condition, which is undoubtedly due to a vasomotor instability, is manifested as an alternating impairment of nasal respiration. The turbinal, although engorged, shows little if any other change. The condition occurs most frequently in sensitive and highly nervous patients who are frequently oversexed. It may be due to an endocrine imbalance or allergic state. The turbinate shrinks readily upon the use of ephedrine or cocaine. In the treatment systemic measures are of importance. In addition one may utilize the *galvanocautery, intramural electrocoagulation,* or *zinc ionization* of the turbinate, as described above.

Chronic Sinusitis

It is beyond the scope of a work such as this to describe even briefly the various factors involving the etiology, symptomatology, pathology, and diagnosis of the various diseases of the paranasal sinuses. Instead, there will be discussed only those pertinent physical procedures that are of value in the diagnosis or treatment of the affections.

Transillumination.—By *transillumination* one can obtain some idea as to the extent or size of a sinus, as well as some conception as to

Insert—Color Plate—pages 23 and 24.

the pathologic process that may be found within its confines. The procedure consists of passing a strong light through the nasal cavity by means of an appropriate transilluminator. The frontal sinuses may be illuminated by placing the transilluminator into the superior internal aspect of the orbit (Fig. 15), well up against the frontal bone. The procedure must, of course, be carried out in a dark room. In health the entire sinus will show an even red illumination. However, if the sinus is absent, or if it contains pus or is lined by a thickened pathologic membrane, the illumination will be absent or decreased, depending upon the condition. One must always illuminate the opposite sinus and use it as a basis of comparison.

The maxillary sinuses may be *transilluminated* by placing the transilluminator within the mouth. One must remember to remove all artificial dentures. Normally there should be an area of illumination about the antral regions, a slightly darkened area over the malar process, and above this another illuminated region under the eyes.

Fig. 15

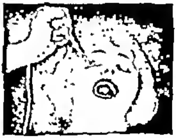

Fig. 16

Fig. 15.—Transillumination of frontal sinuses.
Fig. 16.—Transillumination of the maxillary sinuses.

In addition there is frequently found a red reflex in the pupils. In pathologic conditions the illuminated portion will show varied degrees of shadow, depending upon the degree of pathologic process present. One may also place a transilluminator behind the rim of the orbit (Fig. 16) and note the presence or absence of illumination within the mouth in the region of the palate. It is well to remember that in early pathologic or atrophic processes of the sinus mucosa, the illumination may approach the normal and also that in well-healed membranes the *transillumination* may be decreased and even absent. *Transillumination* should be used only as any other laboratory aid, namely, as a means of confirmation in establishing a diagnosis.

Roentgenograms.—X-rays should also be used as an aid in establishing or confirming the diagnosis; especially since the advent of radiopaque oils, we have a means at our command that may give us minute details as to the nature of the pathologic membrane lining the sinuses. The use of the radiopaque oils is a definite refinement in

nasal fossa, is so characteristic that no further description will be attempted.

The cocci-bacillus of Prez and Abel is supposedly the offending organism and is found in conjunction with many other organisms, especially the pseudodiphtheria bacillus.

In the treatment measures that aid in the removal of crusts are indicated. Various stimulating medicaments may be applied locally. Vaccine therapy has not been successful. Operative measures to decrease the roominess of the nose, such as the submucous implantation of ivory or various other procedures for moving the lateral nasal wall towards the midline, have been advocated with excellent results in many cases. This is especially true in ivory implants. Physical methods have also been utilized. The use of intranasal quartz has been attended with but little success in the authors' hands. More promising is the use of radium. Two 50-mg. tubes of radium screened with 0.2 mm. of platinum and enclosed in a 1-mm. brass tube are inserted against the lateral wall of the nose for one hour on each side. Within a week an acute reaction will occur which subsides within two or three weeks with a decrease in the fetor and scab formation. Three to five such treatments may be given at appropriate intervals. Sufficient experience, however, has not been had with this method, so that further trial is necessary before its worth can be definitely evaluated.

Intumescence of Inferior Turbinal

This very common condition, which is undoubtedly due to a vasomotor instability, is manifested as an alternating impairment of nasal respiration. The turbinal, although engorged, shows little if any other change. The condition occurs most frequently in sensitive and highly nervous patients who are frequently oversexed. It may be due to an endocrine imbalance or allergic state. The turbinate shrinks readily upon the use of ephedrine or cocaine. In the treatment systemic measures are of importance. In addition one may utilize the *galvanocautery, intramural electrocoagulation,* or *zinc ionization* of the turbinate, as described above.

Chronic Sinusitis

It is beyond the scope of a work such as this to describe even briefly the various factors involving the etiology, symptomatology, pathology, and diagnosis of the various diseases of the paranasal sinuses. Instead, there will be discussed only those pertinent physical procedures that are of value in the diagnosis or treatment of the affections.

Transillumination.—By *transillumination* one can obtain some idea as to the extent or size of a sinus, as well as some conception as to

Insert—Color Plate—pages 23 and 24.

Capillary Suction.—Various methods of giving aqueous irrigations have been utilized in the past, but they have been condemned except in certain conditions. The deleterious effect of aqueous irrigation upon the nasal sinus and mucous membrane has been fairly well established both by experimental study and clinical observation; therefore we advocate the use of capillary suction in order to evacuate secretions from within the nasal chambers. The source of the vacuum

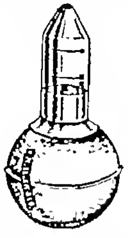

Fig. 17

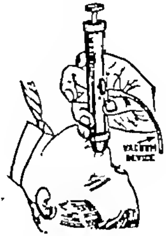

Fig. 18

Figs. 17 and 18.—Suction instruments as used in displacement irrigation of paranasal sinuses.

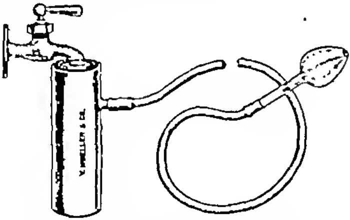

Fig. 19.—Water type suction apparatus, with olive-tipped end.

may be the various power pumps or one of the several types of water suction pumps (Fig. 19). An appropriate handle (Fig. 1), such as the Beck, is necessary. Upon it one may attach relatively large-bore nasal suction tips or the finer-bore aural tips. One may also attach to the handle a trochar that has been introduced into the antrum in order to remove the contained secretions. One may likewise employ the large

diagnostic technic. By these means definite data regarding the size, shape, and position of a sinus can be obtained. Moreover, a clue may be found as to the presence or absence of a pathologic process within the sinus cavity. The use of the oil is especially helpful in distinguishing hypertrophic membranes, cysts, tumors, and mucoceles of the sinuses. Furthermore, by studying the time interval required by a sinus to rid itself of the radiopaque oil, one may obtain some idea as to the functional activity of the ciliary mechanism. A normal sinus should empty itself within from 72 to 96 hr. Should a longer time be required, obstructions to the sinus ostium or pathologic impairment of the ciliary membranes must be considered. The radiopaque oil may be introduced into the sinuses by means of a suitable trochar or the displacement method of Proetz.

Diagnosis.—DISPLACEMENT IRRIGATION.—*For diagnosis, one* may employ lipiodol or bromodol. An x-ray taken with the contrast fluid within the sinus will aid in giving information regarding the pathologic status of the sinus membrane as well as the functional activity. In therapy one may employ various medicaments to affect the sinus membranes. A one-half per cent solution of ephedrine may be used to cause shrinkage of the mucosa and a five per cent solution of neosilvol may act as an antiseptic. Besredka's antivirus may also be used.

Treatment.—DISPLACEMENT IRRIGATION.—A profound effect has been exerted upon roentgenographic technic and interpretation, and to a lesser extent upon the therapy of sinus condition, by Proetz's contribution of displacement irrigation. The problem is to introduce into a relatively large sinus having a small opening some fluid used for either diagnosis or treatment. It is apparent that the fluid can replace the air within the sinus only when the latter has been removed. This may be accomplished by overlaying the sinus opening with the fluid and then exerting a negative pressure over the orifice. This will cause small bubbles of air to be evacuated from the sinus; upon permitting the return of the pressure to normal, the overlying fluid will be aspirated into the sinus to take the place of the air.

In actual practice, this is achieved by putting the patient in a supine position with the head so placed that the orifice of the sinus to be investigated or treated is uppermost. In case of the sphenoid the head is *put into a pendant position so* that *the chin and* the auditory meatus are in the same vertical line. Several cubic centimeters of the fluid are then introduced into each nostril (Figs. 17 and 18), a small hand bulb being used to evacuate the air. The bulb is compressed and tightly applied to one nostril, the other being closed, and the patient is then instructed to say "K, K, K" several times, thus closing the nasal pharynx. At each vocalization, the bulb is permitted to expand, thus producing the negative pressure. This procedure should be repeated several times.

Tuberculosis and Lupus of Nose and Throat

The lesions are not commonly seen except in tuberculosis centers and institutions. In tuberculous ulcerations of the nose, the patient will complain of crusting epistaxis and impaired respiration. Intranasal examination may disclose a typical yellowish ulcer having a characteristic nibbled undermined edge. The lesion will most frequently be found upon the cartilaginous portion of the septum. Lupus of the nose is frequently associated with the same lesion of the face and nasal alae. Here the patient may also complain of nasal blockage and crusting and in addition may have an acrid nasal discharge. Examination may show typical "apple jelly" nodules as well as superficial yellowish ulcerations and rose-colored, raspberry-like granulations.

Treatment.—In the treatment the primary tuberculosis must receive adequate attention. Generalized body irradiation with the *ultraviolet ray*, or *natural heliotherapy*, is of help. Locally one may cauterize the ulcers and granulations with lactic acid or even the *galvanocautery*. Localized *ultraviolet irradiation*, especially with the modified carbon arc lamp developed by Wessely, may be of great aid towards obtaining a cure. The lesion should be irradiated at intervals of one to three days until healing has occurred. The length of the session varies. One should start with three minutes' irradiation and rapidly increase the dosage until a 10 or 15 minute period is developed.

Tuberculous ulcerations of the pharynx may be seen to coexist with a laryngeal tuberculosis. The patient, as a rule, will complain of discomfort in swallowing that may become progressively worse until extreme dysphagia is present. Examination of the pharynx will disclose a typical superficial ulceration having a yellowish base and a nibbled undermined edge. The lesions may be found upon the pharynx, pillars, or tonsils. The treatment is the same as that described for lesions within the nose.

Malignant Tumors of Nasal Sinuses

Carcinoma and sarcoma are the most frequent types of malignancy found in the paranasal sinuses. Although sarcoma appears in the very young, it is just as frequently seen in adult life. Carcinoma, however, appears in the later decades. The symptoms that are most frequently encountered are pain and swelling of the cheek, associated with nasal discharge of a hemorrhagic character and respiratory blockage. Encroachment upon the orbit may cause a proptosis or deviation of the eyeball. The roentgenogram will disclose a blocked-out sinus with definite involvement of the surrounding bony wall. Extension upwards, which is especially frequent in ethmoid neoplasms, is often followed by meningitis; or death may be caused by an extensive hemorrhage or a terminal cachexia.

olive-suction tip to the nose in order to evacuate secretions from the sinuses as a means of diagnosis. The glass olive tip is connected to the suction apparatus and applied to one nostril, the other nostril being closed. The patient is instructed to say "K" several times while the suction is acting. Should there be any purulent secretions within the sinuses, they may be found after this mass suction in the region of the various ostia has been carried out.

Intranasal Quartz Therapy and Medical Diathermy.—In spite of the many enthusiastic reports regarding the use of these two agents in the treatment of sinus and nasal disturbances, we have found that little, if any, benefit has been derived from them in actual practice. General *ultraviolet irradiation* or *natural heliotherapy* may be of some value in the treatment of sinus disease in children.

Nasal Polypi

This rather common rhinologic condition presents such a characteristic intranasal picture that it admits of easy diagnosis. The orthodox removal with a snare and even the performance of an ethmoidectomy do not, as a rule, prevent their recurrence. Several physical measures for limiting and preventing reformation of polypi have been advocated.

Treatment.—*Galvanocautery and electrocoagulation* of the remains, after the removal of polypi, have been advocated. Undoubtedly cicatrization after the use of these agents may prevent or retard the reformation of these growths. However, more extensive trial and observation will be necessary before these procedures can be accepted as safe and effective. The possibility of intracranial complications following these procedures should be borne in mind. It is well to wait a sufficiently long period of time after the surgery has been performed before utilizing *galvanocautery* or *electrocoagulation*. Only small areas should be coagulated at a time and care must be taken to employ only minimal amounts of current.

Radium has also been advocated as a means of preventing or impeding the reformation of polypi after surgical removal. It has been stated that the use of radinm will cause an inhibition in the activity of the nasal mucosa with a decrease in the vascularity by the production of an endarteritis and also with an increase in fibrosis, thus preventing the recurrence of polypi. A 50-mg. capsule of radium properly screened is applied to the ethmoid region and held in place by means of a pack. The radium is permitted to remain *in situ* from two to four hours. If recurrences appear, it is advised that these be removed and the radium irradiation repeated. It is stated that any recurrences which may appear are of a more fibrous character and that there will be no recurrences after the third irradiation. However, we have found recurrences even after four and five treatments.

times. The wound must be packed wide open and carefully watched for any evidence of recurrence. Any suspicious regrowth should be subjected to immediate *diathermic* destruction. If there is any question regarding the lack of innocence of what is apparently a granulation, a confirmatory biopsy should be performed.

It might be well at this time, or shortly after, to introduce four tubes, each containing twelve and one-half milligrams of radium properly

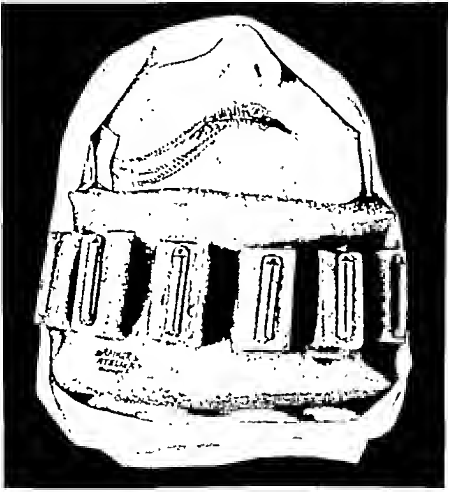

FIG. 20.—Wax cast showing method of applying a radium collar to neck. (Courtesy of Dr. A. J. Larkin.)

screened and left in place for 72 hours. The neck may be irradiated by means of a *radium collar* (Fig. 20), described in the next section, at the same time or at some later period.

It must be admitted that the mutilation and disfigurement with such radical surgery are very noticeable, but one may utilize a temporary prosthesis to cover the defect. The patient must return at

Treatment.—The treatment of malignant tumors of the paranasal sinuses is indeed a melancholy chapter in the practice of medicine. In general the appearance of metastatic glands in the neck presupposes an inoperable condition. However, recent reports shed some encouragement in these cases in which the primary growth has been widely removed and the gland-bearing regions of the neck resected *en bloc* or subjected to heavy *irradiation therapy. Irradiation* with *x-ray* and *radium* for malignancies has, of course, been enthusiastically advocated. The authors' experience has not been very happy; it is better to depend upon thorough radical surgical removal of the growth, leaving the wound wide open for observation, and to utilize irradiation as a postoperative adjunct. The method of choice is *electrosurgery*.

In the use of *electrocoagulation* for nasal malignancies, local anesthesia may be given. However, on account of the extensive surgery to be employed, the authors have utilized rectal ether, avertin, or high spinal anesthesia. Due to the high percentage of secondary hemorrhage, it is well to perform a preliminary ligation of the external carotid upon the affected side. The neck incision should be wide to permit investigation of the cervical lymphatics. Should these be affected, their complete removal *en bloc* after the manner of Trotter is advocated. In some cases it may be necessary to resect muscles and even sacrifice the large vessels on one side of the neck. After the neck operation has been terminated, the face operation may be performed. An appropriate incision over the site of the growth is made and the skin is reflected. In ethmoid and sphenoid growths the incision will be along the inner canthus and side of the nose, and in cases of malignancy of the antrum the same incision may be curved wide across the cheek. The incision may be made with either the cold knife or the tissue-cutting current. The limits of the growth should then be established as accurately as possible and an area of *electrocoagulation* thrown about it well into the healthy tissues so as completely to circumvallate the neoplasm.

At this time it would be well to place a pack into the nose to prevent the entrance of free blood into the nasopharynx. The growth should then be coagulated and removed piecemeal by the curette. The tumor tissue should be followed to its limit, regardless of anatomic considerations. The dura, however, should be properly respected, but if the orbit is invaded and the eye affected, it should be sacrificed. All necrotic bone should be removed and resection of a small portion of healthy tissue about the limits of the growth is advocated wherever possible. The entire wound should then be treated with the coagulating current and hemostasis should be effected. A vaseline gauze pack should then be inserted. If the procedure upon the face is of any magnitude, it is best to perform the sinus and neck operations at different

times. The wound must be packed wide open and carefully watched for any evidence of recurrence. Any suspicious regrowth should be subjected to immediate *diathermic* destruction. If there is any question regarding the lack of innocence of what is apparently a granulation, a confirmatory biopsy should be performed.

It might be well at this time, or shortly after, to introduce four tubes, each containing twelve and one-half milligrams of radium properly

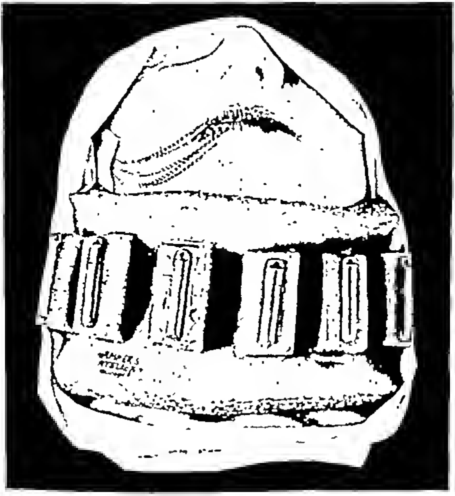

FIG. 20—Wax cast showing method of applying a radium collar to neck. (Courtesy of Dr. A. J Larkin.)

screened and left in place for 72 hours. The neck may be irradiated by means of a *radium collar* (Fig. 20), described in the next section, at the same time or at some later period.

It must be admitted that the mutilation and disfigurement with such radical surgery are very noticeable, but one may utilize a temporary prosthesis to cover the defect. The patient must return at

stated intervals for careful observation of the wound. After the certainty of a cure is established, the defect may be repaired by a plastic procedure or by the use of a permanent prosthesis.

Malignant Tumors of Nasopharynx

Sarcomas, carcinomas, and lympho-epitheliomas are the most frequent types of malignant neoplasms that are found within the postnasal space. The sarcomas, while more frequent during early life, may be found at all ages. Carcinomas may appear in older individuals. The earliest symptoms are nasal blockage, change in voice, and sometimes deafness or middle ear suppuration due to the invasion of the eustachian tube. Hemorrhages are not infrequent. The extension of the growth into the nearby jugular foramen may give rise to the syndrome of unilateral paralysis of the palate, pharynx, tongue, larynx, sternomastoid, and trapezius muscles. As the growth progresses a typical frog-face appearance will be manifested. The diagnosis is, of course, definitely established by biopsy and the prognosis is as a rule grave, if not altogether hopeless.

Treatment.—One may attack the neoplasms with *surgical diathermy* as noted under nasopharyngeal fibroma.

Radium emanation may also be used. Gold seeds containing 1.5 to 2 millicuries to every cubic centimeter present should be implanted. A radium collar should be applied to the neck. This is made by placing 6 tubes containing twelve and one-half milligrams of radium three centimeters apart and two and one-half centimeters from the skin around the neck (Fig. 20). Proper beta screening must, of course, be employed. The collar is then secured by a bandage, which must be renewed daily, and the radium permitted to act for four days, thus giving a dosage of about 7,200 mg. hr. at a distance of two and one-half centimeters.

However, these measures are but palliative in nature and a fatal outcome is the rule.

Nasopharyngeal Fibroma

This rather rare tumor appears as a sessile growth within the vault of the nasopharynx, arising as a rule from the underlying periosteum. It is essentially a tumor of the young, appearing most often between the ages of 10 to 15 years. Although histologically benign, fibromas may become clinically malignant due to encroachment upon vital structures.

The symptoms are mainly those of nasal obstruction and a peculiar change in the voice, a rhinolalia obstructiva. The diagnosis may be easily established by the use of a postrhinoscopic mirror and by pal-

pation. The tumor must be distinguished, however, from a malignant neoplasm.

Treatment.—The surgical excision is a difficult procedure that is fraught with danger. It is best to destroy the growth by the use of *surgical diathermy.* If the neoplasm is small, it may be exposed by pulling the soft palate forward by means of two catheters passed through the nose. If a larger growth is present, the soft palate may have to be split or even an extensive lateral rhinotomy performed in order to secure adequate exposure. The coagulation should be effected

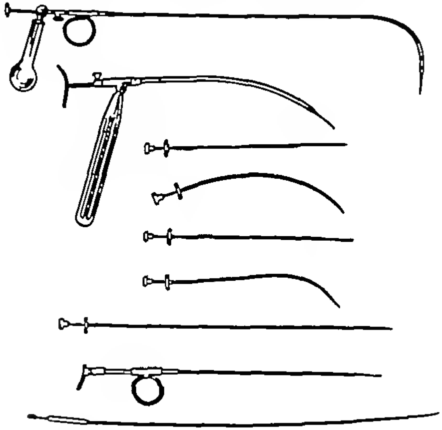

FIG. 21.—Various types of introducers used for implanting radon seeds in malignancies about the nose, throat, and larynx. (Courtesy of Dr. A. J. Larkin.)

in several treatments and a postnasal pack must be held in readiness at all times, to be used in case of hemorrhage.

Radium emanation has also been advocated in the treatment of nasopharyngeal fibromas. Gold seeds containing 1.5 to 2 millicuries may be inserted into the growth by means of an appropriate applicator (Fig. 21), using one seed for every square centimeter of tumor base. The application will have to be repeated at certain intervals.

Chronic Follicular Pharyngitis

This condition, which is frequently seen, consists in the hypertrophy of the isolated lymphoid follicles situated in the pharyngeal mucosa. There may be an associated chronic spheno-ethmoiditis and post-nasal drip. The diagnosis is easily made upon inspection of the posterior pharyngeal wall. Attention to the primary nasal condition is of the utmost importance in the treatment. The individual follicle may be destroyed by *electrocoagulation* with an appropriate elongated insulated electrode.

Alveolar Fistulas

Fistulation into the antrum may be seen following the removal of teeth that have been anatomically related to the antrum. The dental practice of curetting the socket following the extraction, during which the curette is pushed into the antrum, is probably the most important cause of its formation. These fistulas tend to heal provided an extensive sinus infection is not present. However, should there be a great deal of suppuration, tendency towards healing is practically absent, and the fistulas will become lined with epithelial membrane.

The closure may be difficult in some cases. The antrum should receive proper care and an intranasal window or radical sublabial operation may be necessary. The fistula itself may be cauterized with trichloracetic acid. We have had more success by using the actual cautery upon the fistula. Should these measures prove ineffective, a plastic closure involving a sliding mucoperiosteal flap may be necessary.

Chronic Tonsillitis

Diathermy.—Physical agents have been repeatedly advocated as substitutes for orthodox methods in the treatment of chronic tonsillar disease. *Medical diathermy* and *ultraviolet irradiation* to the tonsils are mentioned only to be condemned as of little, if any, practical value. *Surgical diathermy* is a method that may be of value in certain selected cases. The removal of tonsils by means of electrothermic methods cannot, as yet, displace accepted surgical procedures. One may use them in place of certain definite contraindications to surgery, such as diabetes and hemophilia, or in other systemic conditions in which the physical state may make the orthodox procedure hazardous. They may also be utilized when patients refuse the orthodox tonsillectomy due to timidity or apprehension. *Surgical diathermy* has a pronounced field of usefulness in destroying plical overgrowths that are so frequently observed after tonsillectomy. It is also a method of choice in removing portions of tonsil that have been left by inexpert removal. *Surgical diathermy* may be utilized in two ways in the eradication of tonsillar disease.

Radium Therapy.—Radium therapy may be considered in the face of definite contraindications to surgery or surgical diathermy. However, we question the advisability of enclosing a focus of infection in a fibrous scar tissue, as occurs after radium therapy. For those who may wish to utilize radium in chronic tonsillitis, the following technic has been used satisfactorily: The tonsils are cocainized with 10 per cent cocaine applied by a swab and then gold radon seeds containing one or 1.5 millicuries are implanted for each cubic centimeter of tonsil tissue. We have had atrophy occur after using one seed in small tonsils and two seeds in large tonsils.

Tissue-Cutting Current.—The tissue-cutting current may be used to dissect or enucleate the tonsil. This method, however, presents no particular advantages over the ordinary cold scalpel or snare. Although the current may seal capillary vessels, those of moderate size bleed just as readily when cut by the current as when cut during the ordinary surgical technic. Secondary hemorrhage is probably more frequent. For these reasons we have discontinued the use of this type of current in tonsillar surgery.

Electrocoagulating Current.—Surgical diathermy may be used by employing the electrocoagulating current in the piecemeal removal of the tonsils. Small portions of the tonsil may be electrocoagulated, or electrodesiccated, at successive sessions. However, this method in the inexpert operator's hands, at least, is open to question. If the operator is too timid, he may coagulate only the superficial parts of the tonsil and thus seal an infectious process within the crypts. There is also danger of the inexpert operator's going to the other extreme and coagulating beyond the confines of the tonsillar capsule. The integrity of the pillars and the pharyngeal musculature must be as closely respected when using electrocoagulation as when using a knife. Moreover, postoperative sloughing with dangerous secondary hemorrhage is not an infrequent complication. Deep and submerged tonsils may be difficult to treat by the coagulating current without endangering the surrounding structures. We have, therefore, abandoned electrocoagulation of the tonsils except when faced with certain conditions as mentioned above, and employ it mainly for the destruction of tonsillar remnants and plical overgrowths.

Technic of Electrocoagulation.—Local anesthesia of the tonsils, palate, pharynx, and base of the tongue is effected by the use of a 10 or 20 per cent cocaine solution. This solution is repeatedly sprayed or swabbed over the area at intervals of three or four minutes. When anesthesia is complete, the procedure may be started. The patient sits in a chair in an upright position and a large indifferent electrode is placed against the back so as to maintain a firm contact. The apparatus should have been previously adjusted to deliver a current

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away from the pillars. With the electrode properly placed, the current is turned on by means of a foot switch for several seconds until a definite blanched area of two or three millimeters is obtained. Under no circumstances may the blanching approach the region of the tonsillar pillars, as these must always be scrupulously avoided. Several of these punctures are then successively made, the sites being such that the resulting blanched areas will not quite come in contact with one another. It must be borne in mind that the final destruction will extend for several millimeters beyond the area of visible coagulation. About six to eight of such punctures may be made in each tonsil at one sitting. Any bleeding or oozing that may occur is stopped by sparking the bleeding site. In case of submerged tonsils or deep-lying stumps, the pillars must be carefully retracted by the insulated retractor noted above.

After the session the patient is instructed to gargle the throat mildly with any antiseptic mouth wash several times a day and to return for observation at intervals of several days. The patient is further warned that there may be some discomfort and sore throat. Any such disagreeable sequelae may be treated by the use of orthoform or thantis lozenges. Gum containing acetylsalicylic acid (aspergum) may also be of aid when chewed.

The coagulum separates usually within a period of 10 days, after which another treatment is given. In the subsequent treatments, which may number four or five, one must be exceedingly careful to respect the integrity of the pillars and underlying pharyngeal musculature. These boundaries of safety must not be passed and it is well ever to bear in mind that the carotid artery normally lies but one-eighth or one-fourth of an inch beyond the muscular confines of the tonsil, and that in some instances where the artery pursues an aberrant course, it may be in actual contact with the constrictors of the pharynx. That this possibility is not only theoretical is attested by the fact that one of the authors saw *in consultation* one such case, in which an extensive massive hemorrhage followed the unintentional coagulation of the carotid artery.

A number of modifications of the simple technic outlined above have been advocated at one time or another. Those that depend upon the use of button or ball electrodes are mentioned only to be condemned. The bipolar method of tonsillar coagulation in which a metallic pillar retractor is used instead of the inactive electrode at the patient's back has been receiving a great deal of popularity. The use of *electrodesiccation* instead of the *coagulating current* has also been advocated, but as yet has not received universal acceptance.

X-Ray Irradiation.—*X-ray irradiation* for tonsillar disease has fallen more or less into disrepute and is employed only by the occasional enthusiast. However, for those who may wish to use this method,

that will cause an area of two or three millimeters to blanch after an interval of one or two seconds. The different types of apparatus will, of course, require individual settings. Roughly speaking, however, the proper current will be found when the ammeter shows a reading of about three or four hundred milliamperes, with the patient in the closed circuit.

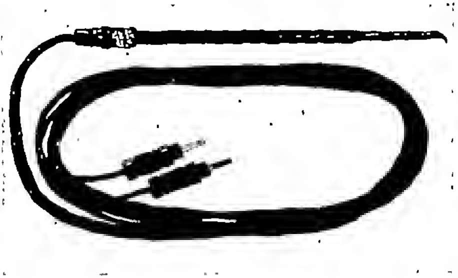


FIG. 22.—Harmann bipolar tonsil electrode.

FIG. 23.—Enlargement, showing construction of tip of Harmann bipolar tonsil electrode.

FIG. 24.—Insulated tongue depressor.

FIG. 25.—Insulated tongue retractor.

A suitable electrode is then selected (Figs. 22, 23). A rubber compound or insulated tongue depressor and pillar retractor (Figs. 24, 25) are utilized to obtain a clear view of the operative field. The electrode is inserted into the supratonsillar fossa to a depth of one or two millimeters. This point of entrance must be at least four or five millimeters

away from the pillars. With the electrode properly placed, the current is turned on by means of a foot switch for several seconds until a definite blanched area of two or three millimeters is obtained. Under no circumstances may the blanching approach the region of the tonsillar pillars, as these must always be scrupulously avoided. Several of these punctures are then successively made, the sites being such that the resulting blanched areas will not quite come in contact with one another. It must be borne in mind that the final destruction will extend for several millimeters beyond the area of visible coagulation. About six to eight of such punctures may be made in each tonsil at one sitting. Any bleeding or oozing that may occur is stopped by sparking the bleeding site. In case of submerged tonsils or deep-lying stumps, the pillars must be carefully retracted by the insulated retractor noted above.

After the session the patient is instructed to gargle the throat mildly with any antiseptic mouth wash several times a day and to return for observation at intervals of several days. The patient is further warned that there may be some discomfort and sore throat. Any such disagreeable sequelae may be treated by the use of orthoform or thantis lozenges. Gum containing acetylsalicylic acid (aspergum) may also be of aid when chewed.

The coagulum separates usually within a period of 10 days, after which another treatment is given. In the subsequent treatments, which may number four or five, one must be exceedingly careful to respect the integrity of the pillars and underlying pharyngeal musculature. These boundaries of safety must not be passed and it is well ever to bear in mind that the carotid artery normally lies but one-eighth or one-fourth of an inch beyond the muscular confines of the tonsil, and that in some instances where the artery pursues an aberrant course, it may be in actual contact with the constrictors of the pharynx. That this possibility is not only theoretical is attested by the fact that one of the authors saw in consultation one such case, in which an extensive massive hemorrhage followed the unintentional coagulation of the carotid artery.

A number of modifications of the simple technic outlined above have been advocated at one time or another. Those that depend upon the use of button or ball electrodes are mentioned only to be condemned. The bipolar method of tonsillar coagulation in which a metallic pillar retractor is used instead of the inactive electrode at the patient's back has been receiving a great deal of popularity. The use of *electrodesiccation* instead of the *coagulating current* has also been advocated, but as yet has not received universal acceptance.

X-Ray Irradiation.—*X-ray irradiation* for tonsillar disease has fallen more or less into disrepute and is employed only by the occasional enthusiast. However, for those who may wish to use this method,

the technic is described. The patient is made to lie prone upon the treatment table with the head turned sharply to one side. The central beam is directed to pass into the side of the neck just posterior to the jaw. Five milliamperes at 100 kv., with a 30 cm. focal spot distance, are given for 5 min. through a 3-mm. aluminum filter, using a 5-cm. lead diaphragm at 15 cm. from the target. Both sides are treated at the same time and treatments may be repeated eight times at weekly intervals.

Papillomas of Oropharynx

Papillomas, which may easily be recognized, are found most frequently upon the palate tonsillar pillars and the uvula. They may be destroyed by resection and electrocoagulation of the base.

Hyperkeratosis of Pharynx and Tonsils

This affection is characterized by the formation of small, whitish masses upon the tonsils, the lower portion of the pharynx, and especially at the base of the tongue. The removal of one of these masses and the examination of it under the microscope will disclose the specific offender, the *Leptothrix buccalis*.

If the affection is localized only to the tonsillar region, removal of the tonsils will be followed by a cure. In other portions of the pharynx and at the base of the tongue the treatment *par excellence* is the use of the sharp tipped *galvanocautery* or *electrocoagulation*. Each of the little specks should be destroyed individually and only a small area should be treated at one sitting. After the procedure one may employ any of the various antiseptic mouth washes.

Lingual Varices

Lingual varices are easily recognized. They may be destroyed by using *electrocoagulation*. An appropriately bent insulated electrode is applied to the enlarged vein and the site of application is controlled by the use of the laryngeal mirror while the patient aids by holding his tongue with a piece of gauze. Great care must be taken not to touch the epiglottis accidentally while the current is acting.

Carcinoma of Tongue

This fairly common condition is not, as a rule, difficult to diagnose. When it is seen early, and especially when it is located on the dorsum or edge of the anterior third of the tongue, it may be amenable to destruction by *electrocoagulation*.

The growth should first be circumvallated by a zone of coagulation extending well into the healthy tissues. The tumor proper may then be destroyed and removed piecemeal. It is probably better to remove too much than too little. If the lesion is at all extensive or if it is located in the posterior aspects of the organ, it might be well first to ligate the lingual artery as a precaution against postoperative hemorrhage. The succeeding wound must be carefully watched and any suspicious regrowth promptly destroyed.

In unfavorable cases *radium* should be used as an adjunct to *surgical diathermy*. In favorable cases radium may be used in the form of gold radon implants of 1.5 to 2 millicuries per cubic centimeter of tissue irradiating at least 0.5 centimeter beyond the margin. The element in the form of needles of 0.5 millimeter platinum wall to the extent of 120 to 160 milligram hours per cubic centimeter may also be used. They may be tied together in pairs or sutured in place singly and spaced parallel to one another 1 cm. apart. Heavy irradiation of the lymphatic areas of the neck should be given (Figs. 26, 27, 28). A radium collar carrying 75 to 100 mg. of radium in six or eight tubes may be used. The screen may vary from 0.5 to 1.5 mm. of platinum, the distance may be 2.5 cm., and the total dosage may be 7,200 to 12,000 mg. hr.

Laryngeal Paralyses

Various types of laryngeal paralyses due to a diversity of causes may be seen by the laryngologist. They manifest themselves by a change in the speaking voice that may vary from hoarseness to complete aphonia. Examination of the larynx may disclose a fixed immobile cord or one that can make only feeble, lazy attempts at motion. The left cord is most frequently involved and may be due to pressure upon the recurrent laryngeal nerve by aneurysm, mediastinal growths and lymphadenopathy, thyroid malignancy, or resection. Bilateral paralysis of the larynx is observed in bulbar disease and after thyroid surgery. Many paralyses are seen in which no definite cause can be found after thorough investigation. These cases are often manifestations of a peripheral neuritis of the laryngeal nerves.

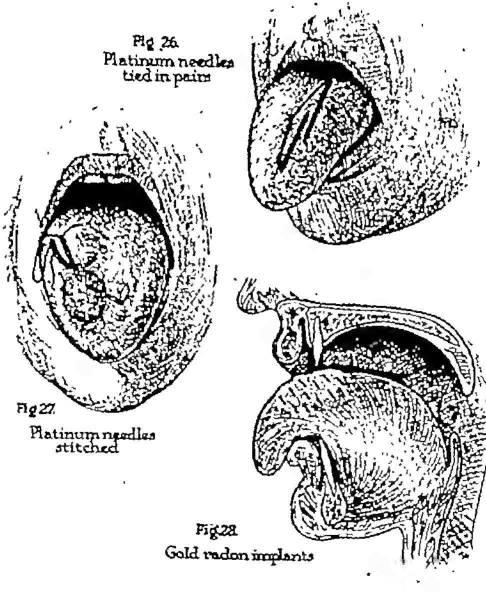
Functional or hysterical paralysis is also seen. These cases have a characteristic bowed appearance of the vocal cords. In addition, corneal and pharyngeal anesthesia, as well as other hysterical stigmas, may be present.

The treatment, of course, depends upon successfully ascertaining the cause and giving it adequate attention. *Physical therapy* may be of value in hysterical paralysis and paralysis due to neuritis.

In the hysterical form of paralysis, the use of the spectacular high-frequency current to energize one of the glowing vacuum tubes, applied about the thyroid region, may be of some value. One may also

use more or less painful faradic applications over the laryngeal region. Psychotherapy is very important in these types of cases and it should be borne in mind that many are resistant to treatment and that the services of a competent neuropsychiatrist may be necessary.

In laryngeal paralysis that is due to a peripheral neuritis, the use of large doses of salicylates may be of benefit. *Medical diathermy* with the electrodes on either side of the neck has been used. Faradic and galvanic currents have also been employed, but the precise value of these measures is problematical.



FIGS. 26, 27, and 28.—Wax cast showing implantation of gold radon seeds into a carcinoma of the tongue. (Courtesy of Dr. A. J. Larkin.)

Papillomas of Larynx

This is frequently an affection of childhood, although by no means is it rare in adult life. It is characterized by hoarseness that may progress to complete aphonia; dyspnea may occur in the later stages. The examination of the larynx will disclose a soft papillary growth which by extension may progress until the entire larynx is filled, and even the subglottic space and trachea may be involved. The involvement of the trachea is prone to occur following tracheotomy performed for the relief of the dyspnea. The diagnosis, as a rule, is easy, although in adults biopsy may have to be resorted to in order to rule out malignancy.

In the treatment one must bear in mind that papillomas of childhood tend towards spontaneous cure by the time the youngster reaches puberty. Progressive hoarseness and dyspnea are indications for exposing the larynx with a laryngeal speculum and removing the neoplasms. The base may then be *electrocoagulated* with a fine current so adjusted as to produce a coagulation of only a fraction of a millimeter. Following such a procedure one must watch carefully for the onset of a laryngeal edema. *Diathermy* does not always prevent recurrences.

Radium has also been advocated for the treatment of papilloma of the larynx. It should never be applied in more than one-half a skin erythema dose, for fear of causing necrosis of the laryngeal cartilage. It may be utilized in doses of 400 mg. hr., using a 0.5 mm. platinum screen at a distance of 2.5 cm. for every two square inches of skin surface. Four to six such portals of entry about the larynx may be used and the irradiation may be repeated after an interval of two months. It has been stated that irradiation may reduce the growth and prevent recurrence. We have never been able to observe the disappearance of the growth following irradiation.

In most cases irradiation has little effect on the progress of the disease and eventually dyspnea may set in which will require a tracheotomy. It is well to warn the parents in advance that such a procedure may become necessary. In those cases in which the entire larynx is filled with the papillary mass, one may resort to the performance of a laryngofissure. The entire growth should then be removed and the base treated by *electrocoagulation*. The tracheotomy tube must then be put into place for several days.

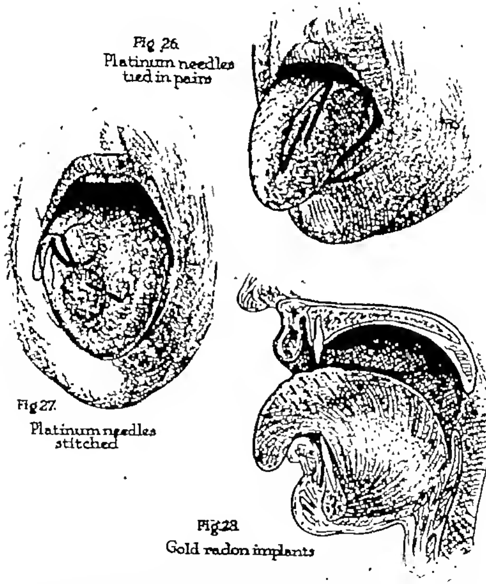
Papillomatous growths through a tracheotomic fistula may be removed and the base *electrocoagulated* in a similar manner.

Tuberculosis of Larynx

This condition is seen, as a rule, as a secondary manifestation of a pulmonary lesion. The symptoms consist, in the main, of hoarseness associated with pain, especially upon swallowing. The larynx may

use more or less painful faradic applications over the laryngeal region. Psychotherapy is very important in these types of cases and it should be borne in mind that many are resistant to treatment and that the services of a competent neuropsychiatrist may be necessary.

In laryngeal paralysis that is due to a peripheral neuritis, the use of large doses of salicylates may be of benefit. *Medical diathermy* with the electrodes on either side of the neck has been used. Faradic and galvanic currents have also been employed, but the precise value of these measures is problematical.



Figs. 26, 27, and 28.—Wax cast showing implantation of gold radon seeds into a carcinoma of the tongue. (Courtesy of Dr. A. J. Larkin.)

control the doses. Rawness and irritability call for an immediate reduction of the time of exposure or even for a short discontinuance.

The carbon arc and mercury quartz lamps may also be utilized in the treatment of laryngeal tuberculosis. It is preferable to expose the larynx directly with one of the various specula made for the purpose and then irradiate. The exposures should closely follow those advocated in the preceding paragraph.

FIG. 19.—Solar laryngoscope in use for the treatment of laryngeal tuberculosis.

X-ray therapy in tuberculous laryngitis has also been advocated, but the results in the authors' limited experience have been so questionable as to cause them to discontinue this method.

The physical agent that has been a sheet anchor in the past and one from which a great deal of benefit may be derived is puncture with the *galvanocautery*. This should not be used in acute lesions of the larynx or in patients with a progressive fulminating pulmonary

show a varied picture. There may be present only a pale interarytenoid swelling of a papillary nature. Other portions of the larynx may have a pale, edematous, infiltrated appearance upon which ulcerations and pale granulations may be found. The epiglottis may have a sausage-like shape and the vocal cords may be characteristically rat bitten. In the presence of pulmonary tuberculosis such symptoms are easy to diagnose. Syphilis and carcinoma may at times be difficult to exclude and may even coexist. The biopsy is necessary to complete the diagnosis.

As with other conditions that are difficult to treat, a large number of remedies have been advocated. The pulmonary condition must receive adequate attention by the chest expert. In fact, the use of lung collapse has effected a decided change in the prognosis of laryngeal tuberculosis. Bed rest, fresh air, wholesome food, and proper climatic conditions are important factors in the ultimate result. Local therapy is important.

The larynx should be placed at rest by maintaining absolute silence, the patient depending upon the use of pencil and pad of paper. Later whispering may be permitted. Pain may be controlled by the use of orthoform or anesthesin lozenges before eating. Cocaine should never be used. Should the pain become severe or difficult to control, the superior laryngeal nerves should be injected with alcohol or even resected.

Local medication to the larynx may be of help. Chaulmoogra oil in a 20 per cent solution may be dropped into the larynx two or three times a week. If extensive ulcerations are present, it might be well to use lactic acid, starting with a strength of 2 per cent and gradually increasing it to 10 per cent.

Physical measures occupy an important rôle in the treatment of laryngeal tuberculosis. *Ultraviolet irradiation* is of definite benefit, especially when associated with proper systemic care. One may use the quartz laryngeal applicators or the reflected sunlight. *Heliotherapy* may be utilized by employing the solar laryngoscope (Fig. 29), a device attached to the back of a chair that contains two mirrors placed upon a suitable support. One of the mirrors reflects the sun's rays into the mouth; from there it is again reflected into the larynx by means of a laryngeal mirror, held by the patient. The other mirror upon the support is used by the patient as a viewing mechanism that permits him properly to reflect the rays into the larynx. The newer modifications that use an alloy of aluminum and magnesium in the reflecting mirrors are to be preferred. This alloy absorbs a large amount of the heat rays and tends to reflect into the larynx a greater percentage of the actinic rays than the usual glass mirror.

The larynx should be exposed, beginning with one minute a day for a week. The irradiation is then gradually increased until ten-minute exposures are being given at the end of several weeks. The laryngologist should examine the larynx at appropriate intervals and

cartilage. A tracheotomy tube may be left in place to care for postoperative edema. The *cutting current* may also be used in the performance of a hemilaryngectomy or total laryngectomy, but it has little if any advantage over the cold knife, in our hands, at least.

Radium and the *x-ray* have been repeatedly advocated. Our experience with *irradiation* has not been a very happy one, since not a single case subjected to such therapy has remained cured. Refinements in radium technic may in the future increase the value of this type of treatment. In consequence we have adopted the attitude of St. Clair Thompson, McKenty, and other laborers in this field, namely, that *irradiation* offers little hope for cure of carcinoma of the larynx as compared to early radical surgery. One may advocate the use of *irradiation* as a postoperative adjunct, but in the light of our present knowledge, our only hope for cure is in the radical extirpation of an early and intrinsic lesion. The loss of the speaking voice may be compensated for by the use of the bucco-esophageal voice or by the use of one of the artificial larynges.

Peroral *diathermic* destruction of carcinoma of the cord, using one of the various means of direct exposure, has been advocated. Unfortunately in several cases subglottic extensions could not be followed and we, as well as others, have been forced to abandon this method.

Laryngeal Stenosis

This condition is most frequently found in children who have been ill with diphtheria. The use of the intubation tube, high tracheotomy, and postdiphtheritic fibrosis all may have a great deal to do with its production. The symptoms in the main consist of hoarseness that may progress to aphonia and an increasing dyspnea and stridor. In the treatment of this condition various plastic operative procedures have been advocated. Recently *physical therapy* in the form of an electrically heated bougie has been utilized (Fig. 31). The bougies, which come in various sizes, may be inserted into the larynx and left in place for 15 to 20 min. The amount of heat and the temperature of the bougie are regulated by the use of a current control. Successively larger bougies are used in succeeding sessions. No anesthetic is required, but the child should be securely wrapped in a blanket. Since the recorded experience with this method is small, its exact sphere of usefulness is, as yet, to be realized.

Carcinoma of the Esophagus

Carcinoma of the esophagus occurs most frequently at the distal portion near the cardia and in the postcricoid region. The latter is more often seen in women than in men. Both squamous cell carcinomas and adenocarcinomas occur. The lesion presents itself most frequently as an endo-esophageal mass, but submucous and peri-esophageal growths

tuberculosis. It seems to serve best in those cases in which the pulmonary pathology is more or less indolent in character.

The procedure is carried out under local anesthesia. The larynx may be cauterized by either the indirect or direct method. In the indirect method the patient is instructed to hold his tongue with a piece of gauze and the operator inserts a laryngeal mirror into the back of the pharynx, thus obtaining a good view of the larynx. The cautery point is then heated to a white glow and, under visual control, plunged into various areas of ulceration, edemas, or granulations. Not more than two or three punctures should be performed at one sitting. The arytenoid regions should be carefully avoided in order to prevent subsequent fixation of the cord. The cautery should not be repeated too often or within too short a period of time.

In the direct method the larynx may be exposed by a Hasslinger or Jackson speculum or even a Lynch-Killian suspension. By means of an elongated cautery point the larynx may be appropriately treated.

We have recently used *electrocoagulation* (Fig. 30) in place of the *galvanocautery,* but the number of cases is too few and the period of observation too short definitely to establish its worth.

FIG 30—Elongated electrode for diathermy of the pharynx and larynx.

Carcinoma of Larynx

This not uncommon disease is characterized by progressive hoarseness, occurring most frequently in men in the so-called cancer age. It is well to note that the lower limit of the cancer age is well below 30 years. The lesion itself may have a varied appearance. It may be only a small pearly nodule located upon one of the cords, or it may have a polypoid or cauliflower appearance. Most laryngeal carcinomas are squamous cell in type and therefore are highly malignant. The diagnosis, as a rule, is not difficult, but frequently one must be able to distinguish syphilis or tuberculosis, which are often simulated. In many cases a biopsy is necessary in order to establish a diagnosis.

The treatment of choice, in most hands, at least, is early and radical extirpation of the larynx. The situation of a laryngeal carcinoma within a cartilaginous box that is only sparsely supplied with lymphatics offers a very good chance for cure. In the presence of small discrete lesions a laryngofissure or hemilaryngectomy may be considered. In the performance of a laryngofissure one may utilize the *tissue-cutting current* for exposing the interior of the larynx and then use the *coagulating current* for the destruction of the neoplasm (Fig. 30). The area of coagulation must extend well into the healthy structures, but due care must be taken in regard to the underlying thyroid

CHAPTER TWENTY-FIVE

PHYSICAL THERAPY IN THORACIC SURGERY

CARL A. HEDBLOM, M.D., AND WILLARD VAN HAZEL, M.D.

INTRODUCTION

Thoracic surgery is largely a development of the past three decades. Asepsis and anesthesia were the prerequisites to the earlier rapid extension of abdominal surgery. Amplification of diagnostic methods and practical means of preventing serious disturbance of respiration and circulation incident to operative pneumothorax were additional prerequisites to a comparable development of thoracic surgery. These additional diagnostic requirements have been fulfilled in considerable measure by roentgenography—made even more valuable by the recent introduction of a nonirritating contrast media, by endoscopy, and by better correlation of findings so obtained with the results of animal experimentation, with pathologic studies and with the clinical manifestations of disease conditions. We have arrived at a better understanding of the mechanisms of respiration. The adaptation of positive pressure pharyngeal or intratracheal anesthesia to its requirements has largely obviated the disturbance of physiologic function during operative pneumothorax.

The diseased conditions of the thorax amenable to surgical treatment include infections, neoplasms and injuries of the pleurae, lungs, chest wall, heart, diaphragm and esophagus. Certain lesions are ameliorated or cured by sectioning the sympathetic innervation through an intrathoracic approach. Some types of thoracic deformities are partly corrected surgically. The transthoracic approach to subphrenic abscess is generally accepted.

The most common surgical disease conditions of the thorax are pyogenic and tuberculous empyema, pulmonary abscess, bronchiectasis and pulmonary tuberculosis. Extrathoracic and intrathoracic neoplasms, both benign and malignant, may be amenable to surgical removal, especially in their early stages.

Physical therapy is a valuable adjunct to the surgical treatment of these diseases of the thorax. Incident to the recent growing interest in physical therapy in general, an increasing measure of attention has been directed to its application in this field.

The most useful physiotherapeutic methods include heliotherapy and its substitutes exemplified in the violet light; heat variously supplied, including diathermy and the infra-red light; radiotherapy, including

are not unknown. The symptoms are mainly those due to obstruction, namely, progressive dysphagia and regurgitation. X-ray examination with a barium meal contrast material will disclose more or less characteristic filling defects. Esophagoscopy is of great aid in establishing the diagnosis, not only permitting visual inspection, but also enabling one to obtain material for biopsy.

The treatment to date is more or less hopeless. If the lesion is located in the cervical esophagus, external esophagectomy may be performed, with a subsequent plastic repair, if no recurrence is observed. The operation is best performed by electrothermic methods, utilizing

FIG. 31.—Electrically heated bougie for treatment of stenosis of the larynx and esophagus.

the cutting current for the dissection and then the coagulating current for the actual destruction of the growth. In other portions of the esophagus, one may utilize irradiation. Radon seeds may be implanted via the esophagoscope; or a capsule of radium may be tied to an endless string after a gastrostomy has been performed, and accurately placed in position by visualization with the fluoroscope. Deep x-ray therapy may also be used. One may relieve obstruction by the use of esophageal dilators, or by the use of electrocoagulation via the esophagoscope, utilizing the elongated coagulating points or buttons. Obstruction may also be treated by inserting a Soutar esophageal intubation tube. Failure of these various measures will lead one to resort to the use of a permanent *Rhefuss tube* or to *gastrostomy*.

from 8 to 12, and during forced expiration from 1 to 2. Vital capacity is the greatest amount of air that can be exhaled after the deepest possible inhalation. In the adult male it is up to 6000 cc.

Under normal conditions an equilibrium of pressure is established between the two pleural cavities by the normally mobile mediastinum. However, if one pleural cavity is opened widely, the lung on that side collapses in amount equal to its elasticity, since the intrabronchial atmospheric pressure is now opposed from without. It can be partly reinflated only by air forced into it from the other lung during expiration, while the glottis is voluntarily closed as during straining. The opposite lung cannot collapse away from its parietal pleura, but it is partly deflated by atmospheric pressure on the mobile mediastinum. The degree of mobility of the mediastinum varies in different individuals. It may be so mobile and therefore bulge so far into the opposite side as to reduce intrapleural pressure there to about atmospheric pressure, even during forced inspiration. Under such conditions no fresh air can enter this lung and asphyxia results.

Various factors influence the degree of actual respiratory embarrassment in the individual patient with a large opening in one chest wall. Chief among them are the size of the unobstructed opening, the degree of mediastinal mobility, and the reserve respiratory capacity. If the opening is smaller than the glottis, the resistance to air entering it is greater than to that entering the glottis. The amount of air entering the bronchi is then proportionate to the difference in resistance to air entering the two openings. If the opening in the chest wall is very large, resistance to air entering it is so slight that practically all the air will enter the pleural cavity during the inspiratory act.

The mediastinum may be stiffened by a preceding inflammatory process, and there seems to be some degree of difference in its mobility in different individuals due to anatomic peculiarities. Under such conditions the degree of embarrassment of respiration is lessened in proportion to its stability. A chronic empyema usually stiffens it to such a degree that it does not bulge at all into the other pleural cavity. The respiratory function of the other lung is then unimpaired by the open pneumothorax.

Since the amount of air that enters the lung is proportionate to the degree of fluctuation in the volume of the pleural cavities and incident fluctuation in intrapleural pressure, it follows that the more vigorous the action of the respiratory muscles, the greater the respiratory or vital capacity.

A normal healthy adult has a respiratory capacity about seven times that used during quiet breathing. He has therefore a large reserve through which he compensates for the handicap imposed by an opening in the chest wall of relatively moderate size. If the opening is very large and the mediastinum very mobile, the greatest degree of compensatory capacity fails to prevent asphyxia. On the other hand, if the patient's muscular power is greatly reduced from any cause such

the use of the roentgen ray and radium; cautery, especially involving the precise application of the electric current; massage; active and passive motion, and the more simple mechanical devices such as splinting and corrective appliances for deformities. Special methods applicable only to the thorax but involving mechanical principles are pneumothorax collapse of the lung, blowing and breathing exercises, positive pressure anesthesia, positive pressure carbon dioxide inflation of the lung, and the respirometer of Drinker.

Physical therapy may be of great benefit, but, generally speaking, it will be an adjunct to, and not a substitute for, adequate surgical treatment. A patient with an arthritis due to an imperfectly drained chronic empyema or abscess will not be relieved of his arthritis by physical therapy of the affected joints. It is useful in rehabilitation after the cause of the process has been removed. Proper indications, relative evaluation in relation to other treatment, and correct dosage are of fundamental importance to the usefulness of any physiotherapeutic method.

Since an understanding of the mechanism of respiration is essential to intelligent and rational surgical treatment of most of the diseases of the thorax, it may not be amiss to review briefly the anatomic and physical factors involved, particularly in the light of the fundamental contributions to this subject by Graham and Bell.

The thoracic cage consists essentially of a bony framework with the intercostal muscles and diaphragm. It contains the lungs, separated by the mediastinum, which is made up for the most part of the heart and great vessels: The lungs in their relaxed state are of smaller volume than the respective pleural cavities. Since the outside of the lung is protected against atmospheric pressure by the rigid chest wall, the unopposed atmospheric pressure exerted from within the bronchi and alveoli stretches the elastic tissue composing them and so dilates the lung to the size of the pleural cavity. The degree of stretch of these tissues determines the degree of less than atmospheric pressure in the potential space between visceral and parietal pleura. During inspiration, which consists of a contraction of the diaphragm, external intercostal and serratus anticus muscles, and during deep inspiration, by the accessory inspiratory muscles, the pleural cavities enlarge in volume and so determine the amount of air inspired. The additional stretch of the elastic tissue of the lung, so produced, augments the degree of less than atmospheric pressure. Quiet expiration consists of simple relaxation of the muscles of inspiration. Forced expiration, accomplished by contraction of the abdominal muscles forcing the relaxed diaphragm higher into the thorax, and by the contraction of the internal intercostal muscles and of the accessory muscles of expiration, decreases the volume of the pleural cavities and so of the lung in amount measured by the expired air. In the adult the less than atmospheric pressure during quiet inspiration is from 4.5 to 9 mm. Hg, and during quiet expiration from 3 to 7.5 mm. Hg. During deep inspiration it measures

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as shock, enfeebling illness of any kind or old age, the respiratory capacity may be reduced to a small margin, and such a patient may not possess sufficient respiratory capacity to compensate for even a relatively small unobstructed opening in the chest wall.

Other conditions influencing the vital capacity in adults are disease conditions that affect the gaseous exchange within the lung itself, such as pneumonia, chronic fibrosis, inflammatory and spastic narrowing of the bronchi, and conditions affecting the respiratory function of the chest wall. Infants are born with lungs nearly as large as the pleural cavities containing them. Their reserve vital capacity is therefore normally very low.

Pressure chambers and the more recent kinds of gas-oxygen anesthesia apparatus represent the application of physical therapy methods designed to overcome the bad effects of surgical pneumothorax. Pressure chambers with negative and positive pressure were first made by Sauerbruch. Intratracheal insufflation followed this method—this being a positive pressure introduction of air through a catheter previously inserted into the trachea. With the extensive use of gas-oxygen anesthesia the problem of surgical pneumothorax has been met. The differential pressure apparatus used in giving gas-oxygen anesthesia provides the positive pressure when it is needed. Experience has shown that the thorax may be opened widely in some cases without harmful effects on the respiration, nevertheless some patients do badly and, for such, this positive pressure equipment should always be available.

The Lundy-Heidbrink and Model G McKesson gas machines, with which a high positive pressure may be obtained, are examples of the type now used. Practically all gas machines are constructed with safety devices against overinflation. A device has been arranged by Dr. Amy Littig called a "bag pressure unit" consisting of a diaphragm, a gage and dial, adaptable to any machine. This records accurately and continuously the exact positive pressure in millimeters of mercury under which the gas is being forced into the lungs. During the closure of the thorax following operation the lung can be almost completely reinflated. The pneumothorax apparatus may then be used to draw off the remaining air, thereby establishing negative tension approximating the normal.

The artificial pneumothorax apparatus is a device for controlling intrapleural pressure. It consists of a manometer scaled in centimeters for pressure readings, and some arrangement for forcing measured amounts of air or gas into the thorax through an ordinary aspirating needle. This is usually done by allowing water from one jar to flow into another jar displacing the air in it, or the fluid may be forced over by means of a bulb such as that employed in taking blood pressure. The air is filtered through sterile cotton. The whole procedure must be carried out under the most strict aseptic precautions. It is employed not only for introducing air or other gas into the pleural space for its therapeutic effect but also, by reversing the system, for withdrawing

air to reduce tension. The manometer only is often used merely to determine the intrapleural pressure (Fig. 1).

The acute thoracic conditions, with the exception of the traumatic, furnish only occasional indications for employment of physical agents. Splinting of the ribs is usually indicated for fracture, and this is easily done by the time-honored method of strapping with adhesive plaster. *After the deepest possible inspiration followed by complete expiration,* the adhesive is applied in the direction of the ribs from the vertebra to the costicartilaginous junction. Marked relief from pain results due to the inhibition of respiratory motion, and healing is probably promoted for the same reason.

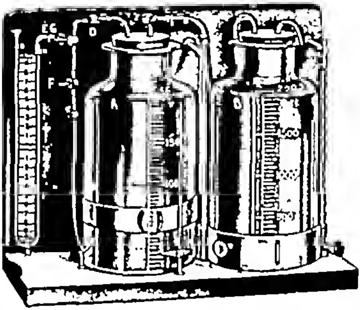

FIG. 1.—Robinson's apparatus for artificial pneumothorax. The apparatus consists essentially of two calibrated jars and a water manometer. The jars are connected by tubing so that water from one jar will flow to the other when the level of one is higher than the other, thereby displacing the air in the jar. The needle, which is inserted into the chest, is connected to the system by means of rubber tubing. By the use of stopcocks, the manometer or the jars can be excluded from the system so that the manometer readings or the introduction of air can be carried out independently as desired. Pressure readings on the manometer may be taken as often as necessary following the introduction of the air, recording accurately at all times the positive or negative tension present. By reversing the ordinary pneumothorax procedure, it is obvious that air can be withdrawn from the pleural cavity as easily as it can be introduced.

Heat in some form relieves pain in traumatic cases. It may be furnished by a large electric light bulb with a reflector, by one of the infra-red ray apparatus, by an electric pad, or by a hot water bottle.

Traumatic pneumothorax is one of the conditions in which the intrapleural pressure is affected. There must be an opening through the chest wall or into the lung for its development. An opening of short duration allowing only a small amount of air to enter the pleural space

calls for no interference. Occasionally a sucking or tension pneumothorax is produced. On inspiration, air is sucked into the pleural cavity, but because of a valve-like action of the opening, air does not escape on expiration. The result is an increasing positive pressure. Continuous ventilation of the pleural cavity through a needle or valve trocar may then be imperative. A wound causing open pneumothorax must be sutured or otherwise closed. Then by use of the pneumothorax apparatus a positive pressure can be reduced to atmospheric or less than atmospheric by the withdrawal of air. This brings relief of dyspnea, and the likelihood of later pleural or pulmonary complications is reduced.

In massive collapse or atelectasis due to retained bronchial secretions, suitable posture may bring relief. Tipping the patient over the side of the bed so that the bronchial secretions will tend to gravitate into the trachea may initiate improvement and ultimate recovery without complications. In a boy, aged 8, following appendectomy under gas-ether anesthesia, massive collapse occurred, proved by x-ray and physical findings. Posture, as described, was sufficient to bring about recovery in two days. Scrimger reports that partial pneumothorax of the affected side has proved helpful. Bronchoscopy has been of value in some instances in removing the retained secretions. Bronchoscopy also is invaluable in removal of foreign bodies of both recent and longer duration. However it should be done only by one skilled in this instrumentation.

Other acute conditions occur which are so closely interrelated with the chronic that they will be discussed together.

Treatment of chronic conditions makes up a large proportion of the work of the thoracic surgeon. Chronic infections often have an extremely debilitating effect upon the patient. This is especially true of empyema, lung abscess, severe bronchiectasis and secondarily infected tuberculous empyema. In such cases vitality is reduced, and the visceral damage may be far beyond what the general appearance may indicate. Some patients may present themselves with a loss of half the body weight, with painful arthritis, secondary anemia of an extreme grade, amyloidosis of the liver which may extend to the umbilicus, impaired renal function and myocarditis. In these conditions physical therapy, supplementary to the more direct treatment, perhaps has not been given the recognition it deserves. With heat, massage and radiotherapy a long convalescence at times can be shortened. Its greatest usefulness is as a supplement to other treatment. Rational use of physical agents will extend their usefulness.

Bronchiectasis

Bronchiectasis is a dilatation of the bronchi with infection giving rise to cough and sputum. In the majority of cases it affects the lower lobes. There is a stagnation of the purulent secretions raised periodically.

Postural drainage often facilitates the evacuation of purulent secretions. Quincke first advised elevating the foot of the bed to promote drainage, and others have found this effective. Some patients find that bending over a chair or the side of the bed is more effective. It may be best to try various positions in order to find the one most suitable to the given patient (Fig. 2). Vomiting is not uncommon during a paroxysm of coughing whether or not posture is employed. For this reason the position should be assumed about an hour before mealtime and at bedtime.

FIG. 2.—Showing posture assumed by patient with bilateral bronchiectasis. She found this more effective than other positions. Following this postural drainage four times a day, she gained fourteen pounds in weight, and the amount of sputum decreased from 800 cc. a day to 150 cc.

Artificial pneumothorax collapse in the treatment of bronchiectasis has yielded fair results. Its success is conditional on the absence of adhesions of the pleurae and the continuance of refills for months. It has been found most useful in the early stages of the disease. Pulmonary collapse by artificial pneumothorax is described more completely under Tuberculosis.

Measures to better the general condition of the patient should not be overlooked. Warm weather and sunshine are of benefit. Direct sunlight, when available, or artificial light is best employed over the entire body. It should be carried out as recommended by Rollier (see Vol. III).

Cautery pneumectomy has been employed with benefit. However, the cases of bronchiectasis where this is indicated border on the abscess type. Therefore in those cases, cautery is used as described under Lung Abscess.

Lung Abscess

Lung abscess is a form of pulmonary suppuration. The treatment varies according to the duration, site of the lesion and condition of the patient. The physical agents that have proved most useful are cautery, bronchoscopy, postural drainage, sunlight and exercises.

The patient with acute lung abscess should be given *postural drainage* as the first method of treatment. It is beneficial in that it lessens toxic absorption and in some cases has led to a cure. If the condition of the patient warrants it, the head should be lowered so that gravity may cause evacuation of the pus at least three or four times a day. There is no definite position which has seemed to be applicable to all patients. Therefore if one position fails to promote drainage, other positions should be tried before the method is abandoned.

Bronchoscopy is employed in selected cases with gratifying results. This form of treatment is most successful in the early cases of abscess located centrally. Its use has been adequately described by Jackson and his co-workers.

The chronic abscess of the lung is the type most often seen by the surgeon.

Postural treatment, as previously mentioned, may be used in the chronic case, particularly where there exist symptoms of toxic absorption, merely as an aid in keeping the cavity as nearly empty as possible.

Pneumothorax collapse is effective in cases in which the abscess lies close to a large bronchus, which means that it is centrally situated. The collapse is achieved by frequent refills of air. If adhesions are present preventing collapse, this method is contraindicated lest the lung be torn and the abscess drain into the pleural cavity, which will lead to a complicating empyema of the most serious type (Fig. 3). Furthermore, if sufficient relief is not obtained by good compression, the air should be aspirated and the abscess drained. A pleural effusion with secondary infection is a frequent complication of therapeutic pneumothorax for abscess.

Of all the physical agents, *cautery* offers most to the patient with lung abscess. Surgical drainage is necessary for a cure in the majority of cases. The procedure for drainage will be briefly described. The abscess having been localized by physical findings and roentgenograms, an appropriate incision is made down to the ribs. A rib may then be resected and the periosteal bed exposed, or, preferably, the intercostal muscles can be divided between the ribs down to the endothoracic fascia. This is done to determine the presence of adhesions. If none are present, a pack may be inserted and the wound closed

for one or two weeks. If drainage is more urgent, a larger window may be made and the lung sutured to the chest wall. With adhesions established, the aspirating needle and syringe are used to locate the abscess. The head of the operating table is lowered to prevent cerebral air embolism from an open vein. Cautery incision, by sealing off the veins which sometimes stand open in the fibrotic lung, prevents such an accident. It also controls bleeding. Either the actual cautery may be

FIG. 3.—Roentgenogram of the chest of a patient with lung abscess treated elsewhere by artificial pneumothorax, illustrating the ineffectiveness of this method of treatment due to peripheral adhesions. The abscess was drained surgically with complete recovery.

used or some form of the coagulation current. Such simple drainage is sufficient to bring about a healing of single cavities. Surrounding pneumonitis, multiple abscess cavities or associated bronchiectasis in chronic cases requires further measures. It is in this type that cautery has been extremely useful (Fig. 4). Graham, first writing on pneumectomy with the cautery, recommended the use of an ordinary soldering iron at red heat over a relatively large area superficially rather than deep into the lung. Repeated cauterizations are safer and better tolerated. He claims that hemorrhage may be controlled by packing and that it is not common after the slough separates. However, every precaution should be taken toward its prevention and prompt control.

FIG. 4—Illustration of drainage wound of bronchiectatic abscess. Several bronchial fistulas are evident. The entire surface shows epithelization due to an outgrowth of the bronchial epithelium

The more recent introduction of the electrosurgical units allows the use of the *coagulation current*. This is a somewhat slower procedure than the actual cautery but there is less likelihood of hemorrhage. The cutting current is hazardous in that it burns so quickly that the depth to which it penetrates may be misjudged, and this may lead to serious consequences. Recently a highly virulent abscess which was draining inadequately was cauterized by introducing the needle of the coagulation current into the surrounding lung in all directions. The patient's general condition responded with surprising promptness, the wound quickly became cleaner, and the amount of drainage decreased

FIG. 5.—Same case as Figure 4, following cautery by use of the electrocoagulation current. The bands have been severed, converting a multilocular cavity into a single one. The epithelium has been destroyed, allowing granulation tissue to form and cicatricial contraction to take place.

markedly. In establishing drainage the electrocoagulation current cautery is a distinct advancement. The incidence of complications is decreased by its use.

One or more bronchial fistulas may persist after the abscess has healed. Some close spontaneously, but others may persist because of the lipping of the bronchial epithelium: This condition can be dealt with most effectively by the repeated use of the coagulation current cautery (Fig. 5) or 20 per cent silver nitrate solution to destroy the epithelium. The resulting granulations gradually lead to fibrosis and cicatricial closure.

During convalescence *heliotherapy* stimulates the appetite and promotes general improvement. Locally it is effective in reducing the amount of drainage. Flick has employed direct sunlight on the draining wounds and believes the secretions are diminished thereby. Graham and Singer regard heliotherapy as an important aid in the healing of an abscess cavity. They believe that the sunlight and ventilation reduce anaerobic organisms and putrefaction. They advise that the body be gradually exposed, including the wound, for a period of one to two hours daily. Coulter chooses to alternate the quartz lamp with the carbon arc. He starts the former at one minute on the first day, gradually increasing up to 15 minutes or longer. Elsewhere in this system (Vol. III) Rollier has carefully outlined his technic.

Recently a child three years of age, following drainage of two abscesses of the lung, was transfused three times and given artificial sunlight treatment. In six weeks her weight had increased from 19 to 30 pounds—over one-third of the body weight.

Pulmonary Tuberculosis

Certain types of pulmonary tuberculosis are amenable to surgical treatment. Rest still remains the basic principle in the treatment. Surgery is a means of increasing the amount of rest of the lung. Some of the physical means employed, such as artificial pneumothorax, cauterization of adhesions, and splinting the chest wall are directed toward the same end.

Artificial pneumothorax has been of tremendous value in the treatment of selected cases of tuberculosis. Forlanini is given credit for its first practical application in 1888. It should be administered only by those who have a thorough knowledge of pulmonary tuberculosis. Unless the indications for its use are present and unless it is correctly used, more harm than good is likely to follow. The indications for its employment and the technical details hardly come within the scope of this paper. As stated, artificial pneumothorax consists of the introduction of air or gas into the pleural cavity, thereby allowing the lung to collapse. Nitrogen gas was formerly used but now filtered air has largely taken its place. The patient lies on the sound side and the skin

is prepared by painting it with an antiseptic. The back, axilla or front of the chest may be the site of election according to the pathology present. The first instillation of air requires special care to prevent injury to the lung if adherent. A free pleural space is shown by fluctuation of the manometer. The normal reading on inspiration is about —6 to —10 cm. of water, oscillating on expiration to —3 to —7 cm. The readings should be taken after a small amount of air has been allowed to enter the pleural space. If the pressure has changed markedly it must be assumed that the needle is in a small pocket which the air has quickly filled. In the average case 250 to 400 cc. can safely be given. In a case of hemorrhage more may be advisable. Refills should be carried out each day for about three days, then every two days, then twice a week, and finally once a week or every two weeks. Thus a complete collapse may be obtained, or if adhesions are present they may allow only a partial collapse. Occasionally filmy adhesions may be broken by slightly increased pressure, but this is often not effective and furthermore is not without danger of tearing the lung, which might result in serious complications. Therefore if attempted it should be done with the utmost caution. High positive pressures should be avoided. The amount of collapse should be carefully ascertained by use of the fluoroscope and roentgenograms.

Therapeutic pneumothorax, like most good methods, has certain limitations. Adhesions may prevent its use. In 1913, Jacobaeus introduced intrapleural pneumolysis as a method whereby in certain cases with adhesions a complete collapse could be secured by severing the bands holding the lung out. By means of a trocar and cannula introduced under local anesthesia, a thoracoscope can be inserted into the pneumothorax cavity and the field observed as the walls of the urinary bladder are observed by the cystoscopist. In favorable cases a cautery electrode is introduced and under visual guidance, made possible by the thoracoscope, the adhesion is severed. The thoracoscope is usually introduced in the interscapular space or below the angle of the scapula, and the cautery in the midaxillary line or more anteriorly. However the position is usually determined by the pathology present. *Galvanocautery* at a dull red heat was used by Jacobaeus, but Matson after using the *electrocoagulation current* believes it will supplant the former because of its sealing and coagulating effects on the tissues, thus lessening the dangers of hemorrhage. He further states that particularly when burning close to the parietal pleura, which is the safest, the heat of the high-frequency current is decidedly less painful. Serous effusion, empyema and hemorrhage have been the most frequent complications.

Following the cauterization, the pneumothorax is left at atmospheric pressure; a negative pressure would favor bleeding; a positive pressure might cause embolism if the lung had been injured and a vein opened. Cough should be controlled. Later, according to Matson, carbon dioxide should be introduced in order to collapse the cavity, and this should be done slowly to allow evacuation of the cavity contents.

Carbon-dioxide is used so that if embolism occurs from it, it will quickly be absorbed into the blood stream. Archibald prefers open thoracotomy for severing adhesions.

Extrapleural thoracoplasty must be resorted to where collapse is indicated and pneumothorax and pneumolysis are not effective. By means of a several-stage operation the posterior segments of the first to eleventh ribs may be resected, affording in most cases a good collapse of the lung and allowing fibrosis and healing to take place. Sometimes where the disease is localized, a partial posterior resection is sufficient to give a good result.

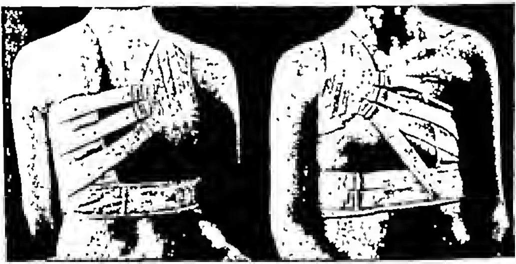

FIG. 6.—Chest splint applied to patient following posterior thoracoplasty for pulmonary tuberculosis of seven years' duration. It gives support to the side until regeneration of the ribs takes place. It also may give some additional collapse in some cases.
FIG. 7.—Anterior view of patient in Figure 6.

Posture following the operation may increase the collapse of the chest wall. By lying on the operated side the weight of the body helps to compress the soft tissues mobilized by the operation. Occasionally, where the mediastinum is not fixed, there may be a certain amount of paradoxical respiration, in which case the same position is invaluable in that the weight of the heart splints the mediastinum. Strapping with wide adhesive may also be worth while in that it stabilizes the chest wall.

Following completion of the operation, a splint such as that used in sanatoria may be employed (Figs. 6, 7). It consists of a broad fabric or suède pad which fits under the arm and is fastened about the opposite thigh and shoulder girdle. It can be tightened and perhaps increases the chest wall collapse; it also has a very decided supporting-effect while the ribs regenerate. It must not limit respiration on the sound side.

A spirometer is an apparatus to determine the vital capacity of the

patient (Fig. 8). This test is useful prior to thoracoplasty. The normal capacity in man is between 3000 and 6000 cc., being a measure of the greatest amount of air exhaled after the deepest inspiration. In tuberculosis this may be much reduced. Normally we have from four to

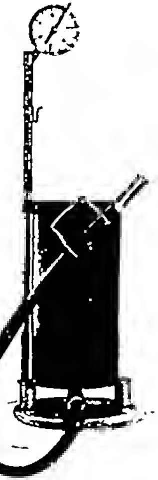

FIG. 8.—Illustration of one type of spirometer for measuring the vital capacity. After the deepest inspiration, the patient expires into the mouth-piece, which elevates the cylinder and records on the dial in cubic centimeters.

seven times as much capacity as is needed for quiet breathing, but if the reserve respiratory capacity is greatly decreased its further reduction by thoracoplasty is contraindicated.

EMPYEMA

Empyema is an accumulation of pus in the pleural cavity. It follows pneumonia, influenza and trauma or may complicate pulmonary tuberculosis. Tuberculous empyema presents a different problem from the pyogenic type and therefore will be discussed separately.

Acute empyema is usually a complication of a sudden severe illness which has left the patient in a weak condition. The added strain of a new infection, with its attendant fever and other manifestations of toxic absorption, may reduce him to a critical condition. The fundamental principle of treatment is evacuation of the pus. In small children and occasionally adults, repeated aspiration has resulted in recovery. However, two methods, the closed and open, are the accepted methods of treatment. In the closed method the pus is evacuated by the introduction of a catheter into the pleural cavity by means of a trocar and cannula inserted through an intercostal space and suitably fixed in place; in the open method, by the resection of a seg-

FIG. 9.—Illustration of a McElroy syringe, the barrel being used as a funnel in a case of acute empyema treated by the closed method. The irrigating solution is allowed to flow into the empyema cavity by gravity, thereby avoiding overdistention.

ment of one or more ribs and providing wide-open drainage. In the case of the critically ill patient and in the acute stage of the streptococcic type of empyema which is seen following epidemic influenza, there remains no choice as to type of operation. The closed method here is mandatory in that it is a much less formidable operation than resection of a rib, and furthermore it provides against the reduction of the vital capacity in those patients where the mediastinum is not fixed. During the epidemic of 1918, postinfluenzal empyemas showed a very high mortality, partly due to the virulence of the organism, but likewise to the open pneumothorax created by resection of one or more ribs, resulting in a collapse of the lung and often a shifting

FIG. 10.—The piston has been introduced into the barrel. By a back-and-forth motion of the piston the pus is mixed with the irrigating solution and then removed. This procedure is continued until the washings are clear. The tube is clamped between irrigations

of the mobile mediastinum, and leading to marked impairment of the respiratory capacity. The more general adoption of the closed method of treatment in ordinary cases has been followed by improved results.

Adequate drainage must be maintained all of the time. For this purpose numerous methods have been devised. The more simple the procedure, the more universally applicable it is to all cases, providing it fulfils two cardinal principles—namely, adequate drainage and restoration of function to the partially collapsed lung.

A McElroy syringe, such as illustrated in Figure 9, serves very well for aspirating the pus and for irrigating the cavity. The barrel may be used as a funnel, and the irrigating solution, preferably Dakin's, where no bronchial fistula exists is allowed to flow into the cavity by gravity, thereby avoiding too great amount of pressure. The solution is thoroughly mixed with the pus by a back-and-forth motion of the syringe, and each time more solution is removed than introduced (Fig. 10). This causes a gradual reëxpansion of the lung. The Dakin's solution also is an excellent solvent for removing the fibrinous exudate from the walls of the pleurae, thereby reducing to a minimum the thickening of the same and fibrosis of the underlying lung. In ordinary cases this procedure is carried out every two hours during the day. Where the toxicity is great, it is advisable to increase the frequency of irrigations during the day and also to irrigate several times during the night.

Some prefer to use continuous suction. By means of several bottles at different levels a solution can be allowed to flow into the pleural cavity, and by siphonage it is continuously withdrawn. Buelau, Perthes and Morrelli have described different types of apparatus for this purpose. Some prefer open drainage. It involves resection of segments of one or two ribs and the insertion of tubes. It calls for no physical agents to facilitate drainage.

Adequate drainage having been established, the next step is to restore function of a partially collapsed lung. Whatever method is used to bring about drainage, reëxpansion of the lung can be hastened by the same means.

Blow bottles, or Wolff bottles, are of distinct advantage (Fig. 11). By blowing water from one bottle to the other the lungs are inflated to their capacity; which promotes obliteration of the cavity. Children may find balloons or horns more to their liking, or the water may be colored in the bottles, creating a greater interest. Other physical agents are usually unnecessary in acute cases.

Chronic empyema, however, presents a different problem. Chronicity is due in the majority of cases to inadequate drainage, but other causes are bronchial fistula, foreign bodies, tuberculosis and osteomyelitis of the rib. Here again drainage must be established by one of the methods described under the acute condition. Likewise, the blowing exercises should be employed in order to restore as much function as possible.

Empyema with Bronchial Fistula.—Bronchial fistula not infrequently is the cause of chronicity. Some bronchial fistulas close when adequate drainage is established; others do not, and such fistulas are the underlying cause of failure to obliterate the cavity. Cauterization with the coagulation current is both effective and safe in promoting its closure. It destroys the bronchial epithelium lipping the opening and leads to granulation and scar tissue contraction. This type of current is safer than silver nitrate stick in that secondary hemorrhage is less

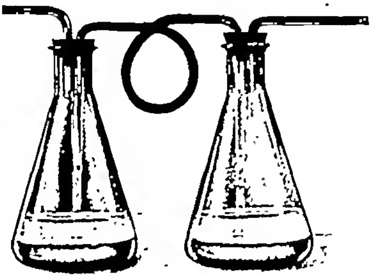

FIG. 11.—Wolff bottles. The water is blown from one flask into the other, thus increasing intrabronchial pressure which tends to aid in expansion of the lung. It is by reëxpansion of the lung that the empyema cavity is obliterated.

likely following its use. Repeated cauterizations may be necessary to bring about closure, which should not be attempted if there is any evidence that the bronchus is draining a pulmonary suppurative process.

Atrophy of the muscles and arthritis are often observed in chronic empyema. Massage can be used to bring about better muscle tone until the patient's condition warrants active exercise. With the focus of infection gradually diminishing through drainage, the joints should also receive *massage* as suggested by Mock for rheumatoid conditions (see Vol. II).

Proper *exercises* are indicated where there is limitation of motion or function.

Heliotherapy may be advantageous for the patient barred from sunlight and fresh air by a prolonged critical illness.

Tuberculous Empyema.—Tuberculous empyema without secondary pyogenic infection is not amenable to the principles which guide the treatment of the pyogenic type. A tuberculous empyema may exist as a primary lesion; that is, a tuberculous pleuritis may be present with no demonstrable pathology in the underlying lung. The culture and smear show no organisms with the exception that sometimes the tubercle bacillus may be demonstrated. In some patients, when no pressure symptoms arise, the pus may be left undisturbed for a time; in others, oleothorax is used with varying success. Aspiration of the pus with replacement with air by use of the pneumothorax apparatus may be highly beneficial. This is especially true where toxic absorption is evident. The pressure is usually left at about that of the atmosphere. Reëxpansion of the lung is desirable here, and this is gradually brought about through absorption of the air. Forced expansion through the use of blowing bottles or similar devices is not desirable.

Tuberculous empyema, however, not infrequently complicates a clinically evident pulmonary tuberculosis. The underlying lung may present physical findings suggestive of the disease, or the roentgenogram may show cavities or evidence of tuberculosis where the empyema is not massive enough to obscure the entire lung field. If both are masked the history may determine the presence of lung involvement. If the pus shows no pyogenic organisms, the purulent effusion may be undisturbed for a time at least. It compresses the underlying diseased lung which may lead to considerable improvement. However, aspiration with replacement by air may be still more beneficial. It is absolutely essential in this type, however, to continue the partial or complete collapse of the lung, as the case may be, in order to insure permanent healing of the lung. Reëxpansion of the lung before the lesion is healed is contraindicated. A thoracoplasty may be the only means of curing persistent tuberculous empyema with pulmonary involvement.

Tuberculous empyema assumes a different status when pyogenic organisms complicate it. If the infection is extremely mild, aspirations occasionally control the toxic absorption. Where a major surgical procedure is not contraindicated a thoracoplasty is advisable. Usually the infection demands drainage by the closed or open method, followed later by extrapleural thoracoplasty. Here again the condition of the underlying lung is the criterion on which the treatment is based. With extensive pulmonary involvement, no procedure to promote reëxpansion of the lung should be employed.

Carcinoma of the Lung

Radium is palliative in carcinoma of the lung. Where the tumor is situated in the periphery of the lung it can be reached by thoracotomy. *Radon implants* can be distributed through the mass. Three patients with pain as the most pronounced symptom were markedly relieved

for months by such treatment. One, a farmer, took a new interest in his work for eight months after its use, though he had not been able to work for a year previous to this time. Another, a woman, who had large amounts of pleural fluid necessitating repeated aspirations, required but one aspiration during the succeeding six months that she survived. She was much more comfortable possibly because of the absence of fluid. Still another, with severe pain in the arm due to pressure on the brachial plexus, was afforded relief until his death eight months later. Some of this relief may have been due to the resection of a segment of rib. However, with the slow growth of the tumor, the recurrent pain was not as severe as prior to the implantation of the radon seeds. In our experience no untoward effects or complications have followed its use.

Drinker Respirator and the Pulmotor

The Drinker respirator and the pulmotor should be mentioned as physical agents invaluable in cases of interrupted respiration. In the respiratory muscles, ascending paralysis of poliomyelitis, in drowning and carbon monoxide poisoning they have been of utmost value. Undoubtedly wider application will be found for the Drinker apparatus. The descriptions and more complete details of the uses of these devices appear in Volume I of this work.